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VOL. 18, NO. 1 March, 1943

THE QUARTERLY REVIEW
of BIOLOGY

THE BIOGEOCHEMISTRY OF ALUMINUM AND OF CERTAIN RELATED ELEMENTS

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"unobserved proprieties, not only in the vegetable shop, but the whole volume of nature"

THE present review was undertaken as part of a comprehensive work on the chemical factors of the environment that operate on living organisms. The preparation of such a work is of necessity a protracted task, and is likely to proceed more slowly at the present time than in normal years. It has therefore seemed appropriate to offer for publication one completed section, the more so in that this section affords an opportunity to discuss certain general principles that have been largely overlooked in the past. Three of the elements discussed, namely aluminum, gallium, and scandium, have recently been shown to play hitherto unsuspected parts in the metabolism of certain organisms; a review of the biology of these metals may therefore provide a useful background for further studies of their biochemistry.

In scope the present account is limited to what may be called the natural history of the elements discussed, pharmacological and toxicological considerations, and discussion of the uses of the elements as implements of physiological research being entertained only when they throw light on the normal cycles of the biosphere. The elements treated are those of group III of the periodic table (Al, Ga, In, Tl, Sc, Y, and the lanthanide rare earths), but only non-radioactive metals are considered. Boron has not been discussed because its chemical similarities to the other members of the group are limited mainly to rather formal analogies of no biochemical significance; its cosmochemical and geochemical history is very different from those of the elements treated. Moreover, in spite of the enormous body of work done on the agricultural biochemistry of boron, its metabolic rôle is still subject to much doubt and any review at the present time would probably be of ephemeral interest. Actinium has not been considered because its geochemical distribution depends on that of its ancestral elements, and its natural biological occurrence, though apparently recently under investigation in Vernadsky's laboratory, has never been discussed in print.

In searching the literature, the Bibliography published by Willis (1939–42) and the review of Kehoe, Cholak, and Story (1940b) as well as other reviews mentioned below, have been most helpful. As far as possible all the papers cited have been studied in the original texts. The rarity of certain of the older works and the present inaccessibility of recent European publications has, however, often made such study impossible. All works known only as abstracts are noted as such in the bibliography. In certain cases, where a paper has been discussed by a series of authors who have clearly never read the work in question, reference to the original has disclosed a content quite different to that traditionally assigned. It is too much to hope that some new errors of this sort are not

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undergoing gestation in the present contribution. Moreover, the extent of the field that had to be surveyed is so great that preparation of the work involved trespassing on the domains of many different kinds of workers. If they have from time to time been misunderstood and misinterpreted, it can only be hoped that the general view obtained will compensate for inevitable errors in some of the details.

The term Biogeochemistry, employed in the title, originates with Vernadsky who (1939) writes,

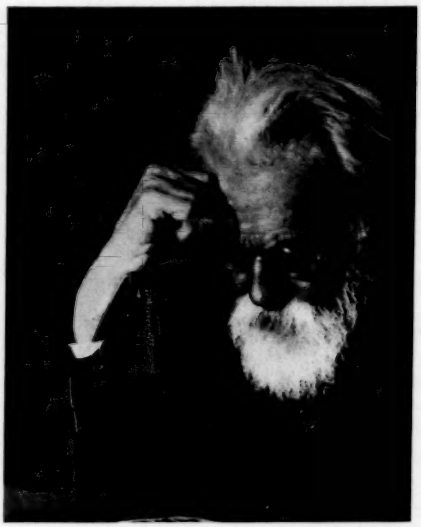


FIG. 1. ACADEMICIAN W. I. VERNADSKY

"Biogeochemistry, which is a part of geochemistry and has peculiar methods and peculiar problems of its own, may be finally reduced to a precise quantitative mathematical expression of . . . living nature in its indissoluble connection with the external medium. A living organism thus acquires an aspect different from the one it has in biology; it is expressed in . . . atomic or weight composition, in physical quantitatively expressed, manifestations of the space it occupies, in . . . energetical expressions of the work it does in the space of life upon our planet. . . . Hence it seems to me that in the phenomena of life we may approach in a new way a number of fundamental problems . . ., on one hand, and on the other, relate the biological phenomena with the branches of science dealing with atoms, i.e., with that field of science, which distinguishes our epoch from the preceding ones."

In the later part of the review concepts will be introduced derived from the geochemical work of V. M. Goldschmidt, concepts that depart in various ways from the general mode of approach of Vernadsky and his school. To the present writer, the most fruitful approach to the fundamental problems of ecology lies in a synthesis of the results of Vernadsky, Goldschmidt, and certain other investigators entirely outside the traditional field of the biological sciences. The initial inspiration to attempt such a synthesis was derived by the writer long ago from conversations with his father, the late Arthur Hutchinson, F.R.S., sometime Professor of Mineralogy in the University of Cambridge, England. The writer wishes to express his gratitude to Professor George Vernadsky for the beautiful photograph of Academician W. I. Vernadsky that constitutes Fig. 1, to Dr. Edgar J. Boell, Dr. Donald J. Poulson, Dr. Edward S. Deevey, and the late Dr. Raymond L. Lindeman, who have read sections of the manuscript, to Dr. Rupert Wildt for opportunities to discuss cosmochemical problems, to Professor Alexander Petrunkevitch for help with several important papers in Russian, to Professor Alfred R. Bellinger for help with certain Latin texts, to the staff of the Yale University Library for assistance in certain difficult bibliographic problems, to Mr. Sidney S. Labovitz, who has given immense help in the preparation of the bibliography, and to his wife, who, as *arbitra elegantiae* in matters of presentation and style, has been of more assistance than can easily be acknowledged.

PRELIMINARY DATA ON THE GEOCHEMISTRY OF ALUMINUM

Though the third most abundant element of the accessible parts of the lithosphere, following oxygen and silicon, aluminum is clearly less abundant cosmically than either magnesium or iron. Reasoning from the composition of meteorites, it seems certain that almost the entire terrestrial supply of the element entered the silicate phase of the cooling earth. Aluminum, like the other elements forming ions of the rare gas type, is therefore to be regarded as a *lithophil* element. Further comparison of accessible terrestrial rocks with meteorites indicates that during the crystallization of the silicate phase, aluminum differentially entered the later crystallizing fractions, so that while in the silicate meteorites the most acceptable mean content is 1.79 per cent, in the accessible lithosphere it is 8.13 per cent.

Like the other strictly lithophil elements, aluminum is never found naturally in elementary form, and the occurrences as unhydrated oxide

(corundum, ruby, sapphire) or as the trisodium aluminum hexafluoride, cryolite, are insignificant from the standpoint of the present review when compared with the enormous quantities of aluminosilicate rock-forming minerals. Among the more important of such rock-forming minerals are the feldspars, the lattice structure of which consists of a three dimensional network built up of tetrahedra of ionised oxygen atoms, in the centre of each of which is either a silicon or an aluminum atom. This network is electronegative, the charge obviously depending on the ratio of Al^{+++} to Si^{++++}, the number of oxygens being constant. In the interstices of the net the larger mono- and divalent cations, sodium, potassium, calcium, barium, etc., are held. When there is much aluminum, the excess negative charge will be balanced by divalent ions, as by calcium in anorthite $CaAl_2Si_2O_8$, or, more rarely, by barium in celsian $BaAl_2Si_2O_8$; when little aluminum is present, by monovalent cations, as sodium in albite, $NaAlSi_3O_8$, or potassium in orthoclase $KAlSi_3O_8$. For further details the reader is referred to any recent work on crystal chemistry, notably that of W. L. Bragg (1937).

With regard to its fate in the final decomposition of the primary aluminosilicate rocks, the place of aluminum may be exhibited in general by adopting the convenient diagram prepared by Goldschmidt (1937) in which the lithophil and atmophil elements of invariant valency are entered as points of which the coordinates are (r) the ionic radius (in ionic crystal lattices) and (z) the ionic charge (i.e., valency). Goldschmidt points out that the elements of low ionic potential $\left(\frac{z}{r}<4\right)$ can in general exist as soluble cations, those of high potential $\left(\frac{z}{r}>12\right)$ unite with oxygen to form complex soluble anions while the elements of intermediate potential in general form insoluble oxides or hydroxides on weathering. The value of this diagram in coordinating certain biological results will be apparent in the closing sections of the present review (Fig. 7).

The hydrated oxides of aluminum, though the simplest decomposition products of the minerals of aluminosilicate rocks, are by no means the most interesting. A variety of minerals exist which may formally be regarded as the products of hydrolytic decomposition of feldspars. The micas forming important macrocrystalline constituents of deep rocks, or kaolinite formed by hydrothermal activity remote from the biosphere are among the more familiar substances of this kind. Biologically the clay minerals of soils, though less generally known, are of far greater importance.

The exact mechanism of the decomposition of the primary rocks is still a matter of active investigation. It has long been known that finely divided igneous rocks can be decomposed slowly by treatment with water containing carbon dioxide in solution (Müller, 1877; Daikuhara, 1914). The carbon dioxide normally acting in nature in water of superficial origin is primarily of biological derivation, and this, the simplest method of decomposition in the biosphere, is therefore a process that Vernadsky (1938) would characterize as *bio-inert*. There is, moreover, ample evidence that hydrogen clays and acidic organic colloids act in a comparable manner. Graham (1941) has shown that hydrogen-saturated colloidal clay can remove calcium from anorthite particles of silt size; since the calcium ions can then be given up to plants a partially biological cycle is thus established. Hydrogen-saturated organic colloids, the humic acids of the older workers, are, however, still more effective in this way (Graham, *in* Albrecht, 1941). Vernadsky (1938, 1939) considers that bacteria and possibly soil diatoms play a considerable part in the changes undergone by aluminosilicates in the soil; unfortunately no detailed reports are available on the recent investigation of this matter in his laboratory. It is, however, clear that living matter and its decomposition products have played an enormous part in the superficial changes in the aluminosilicates that form, to use Vernadsky's picturesque expression, the "skeleton of the biosphere." In turn the partially resynthesized products of the decomposition of rocks exercise a great influence on living organisms.

Just over a century ago Liebig (1840, p. 129) wrote,

> "In dem Thon muss an und für sich eine Ursache vorhanden sein, welche Einfluss auf das Leben der Pflanzen ausübt, welche directen Anthiel an ihrer Entwickelung nimmt. Diese Ursache ist sein nie fehlenden Kali- und Natrongehalt [The 5th revised edition of 1843, p. 147, reads "sein Gehalt an Alkalien, alkalischen Erden, an phosphorsauren und schwefelsauren Salzen"]. Die Thonerde nimmt an der Vegetation nur indirect, durch ihre Fähigkeit, Wasser und Ammoniak anzuziehen und zurückzuhalten, Antheil, nur in höchst seltenen Fällen findet sich Thonerde in den Pflanzenaschen. . . ."

It is to the special function of clay minerals, as regulators of the migration of so many other ele-

ments, that the aluminosilicates owe much of their importance. As an integral part of these compounds, aluminum loses a great part of its biological importance as we approach the living cells, whether of the plant root or of the soil protozoan, which the aluminosilicates surround and support, regulating their water content and directly or indirectly their nutrient supply. No adequate account of these processes, which constitute the main subject matter of pedology, can be given in this review. Since, however, it is necessary to discuss some of the aluminum compounds of the soil in relation to the aluminum content of organisms, a brief account of the chief aluminum-containing substances of the pedosphere is given in the next section.

ALUMINUM IN THE PEDOSPHERE

Aluminum exists in soils, in the immediate environment of soil organisms and of the roots of plants, as (cf. Mattson, 1941)

(a) undecomposed fragments of aluminosilicate rocks, the feldspars and micas being usually the most important. These fragments may be macroscopic, microscopic, or ultramicroscopic in size.

(b) the aluminosilicate complexes of clays and soil colloids, derived by weathering from aluminosilicate rocks, but by processes that involve synthesis from simpler decomposition products.

(c) colloidal and undispersed hydroxides, perhaps forming a heterogeneous gel and sol complex with hydrated ferric oxide, hydrated silica and organic compounds.

(d) aluminum phosphate, which in more or less leached soils is an important source of phosphorus.

(e) a true solution in the water of the soil.

The larger undecomposed rock fragments dissolve so slowly that at any monent they play a relatively small part in the aluminum cycle of the soil. If, however, primary rocks are sufficiently finely divided, by mechanical means, up to about 95 per cent of their contained alkalies, and alkaline earths, become exchangeable (Jackson and Truog, 1939). It is clear that the ordinary processes of weathering coupled with the production of aqueous solutions containing CO_2 and organic colloids of biological origin are sufficient to produce not merely mechanical but also chemical changes in the distribution of the components of aluminosilicate rocks.

Aluminum minerals as soil colloids

It is now generally agreed that the inorganic colloidal matter of soils consists mostly of a series of definite minerals, highly dispersed, but showing typical crystalline structure. Simple discussions of these substances are given by Kelley, Dore, Woodford, and Brown (1939) and by Hendricks and Alexander (1939) and Alexander, Hendricks, and Nelson (1939), and, in greater detail, in the admirable symposium articles by Grim (1942), Hendricks (1942), and Kelley (1942). The appearance of such colloidal particles in electron microphotographs indicates that the individual crystals are platelike in shape like the macroscopic crystals of mica. They consist of more or less independent layers of charged atoms held together only by residual forces. Such layers are typically formed of two or three sheets of ionised atoms. The fundamental structural units may be regarded as of two kinds. The first is composed of silicon atoms surrounded by four oxygen atoms. Three of these four tetrahedrally placed oxygens lie in a plane and with others similarly placed form a hexagonal network indefinitely extending in two dimensions. The second unit consists, in the simplest case, of a sheet of aluminum atoms equidistant between six oxygen atoms or hydroxyl groups. The oxygen atoms of this aluminum sheet are the atoms coordinated with silica but not involved in the hexagonal net. In general three types of clay minerals can be recognized. In the simplest type, namely kaolinite and related substances, the layer lattice is composed of one silica (tetrahedral) and one alumina (octohedral) sheet. The other types contain fundamentally two silica sheets and one aluminum sheet. In the illite series some of the tetrahedrally coordinated Si^{++++} is replaced by Al^{+++} and the charges are largely balanced by K^{+} between the complex layers. In the montmorillonites it is probable that the direction of the tetrahedra alternates and that hydroxyl groups project into the spaces between the layers. Water and cations can be held in these spaces, causing a great separation of the layers. The maximum expansion possible appears to be from 9.6Å, the height of the unit without water, to 30Å. Diagrams of the three types of lattice, as elucidated by the most recent studies, are given by Grim (1942) and are here reproduced (Fig. 2).

The most important property of all these minerals, but particularly of the montmorillonites, is the ease with which various cations can be held superficially in the lattice and can pass into the dispersing aqueous phase in exchange for other cations. This property is presumably largely due

to substitutions in the fundamental structure indicated above, producing charges that can only be satisfied by ions from the outside. Some substitution of the H of hydroxyl ions at broken edges, or if the structure here given for montmorillonite be acceptable, on the basal planes, is also possible. In the case of kaolinite, substitution of hydroxyl for phosphate ions may be important (Stout, 1939), though apart from this case anion exchange has been little studied. A scheme for the montmorillonite group based on lattice substitution has been developed by Ross and Hendricks (1941; Hendricks, 1942). In a mineral such as pyrophyllite which may be represented as $Al_2 \cdot Si_4O_{10} \cdot (OH)_2$, the aluminum is entirely in octohedral, the silicon in tetrahedral coordination, and all the charges are balanced. In talc, the two aluminum atoms are replaced by three magnesium atoms, but the number of positive charges remains the same so that the sheet as a whole is uncharged. In ordinary states of dispersion no base exchange occurs between these minerals and the cations of the medium.

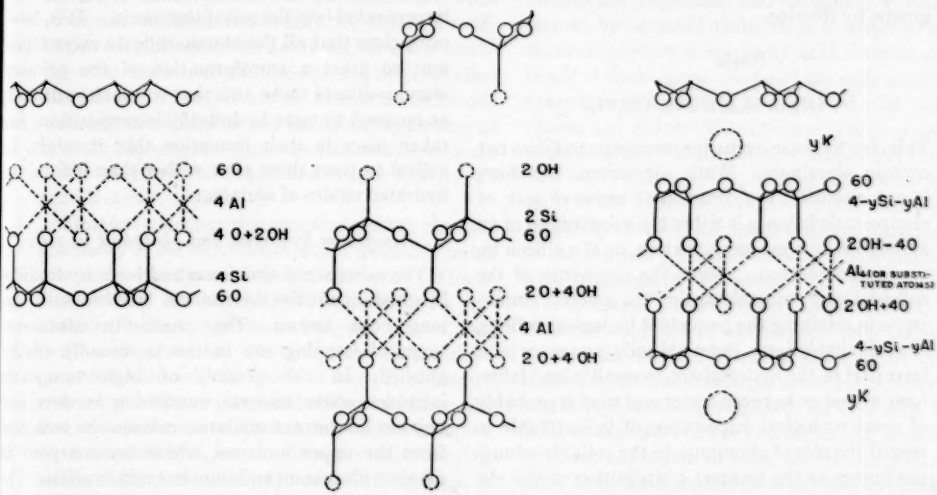


FIG. 2. LATTICE STRUCTURE OF THE THREE PRINCIPAL TYPES OF CLAY MINERALS OF THE BIOSPHERE
LEFT—KAOLINITE; CENTER—MONTMORILLONITE; RIGHT—ILLITE
(After Grim, 1942)

In montmorillonite we have a somewhat intermediate condition to that found in pyrophyllite and talc, namely $(Al_{1.67} \cdot Mg_{0.33})(Si_4)O_{10}(OH_2)$. One in six aluminum atoms is replaced by a magnesium atom, but this involves substituting a doubly charged for a triply charged cation, so that the excess charge can be balanced as indicated by the sodium atom above the arrow; this atom can be replaced by another cation in solution in the dispersing phase and so is termed replaceable or exchangeable.

$$\overset{\overset{Na_{0.33}}{\uparrow}}{(Al_{1.67} \cdot Mg_{0.33})(Si_4)O_{10}(OH_2)}$$

Of greater importance in many soils is a colloidal mineral in which some of the tetrahedrally coordinated silicon is replaced by aluminum. The resulting negative charge is in part balanced by an excess of aluminum in octohedral coordination, in part by a replaceable cation associated with the tetrahedrally coordinated aluminum. Magnesium appears to be much reduced in such minerals. The typical clay mineral of this kind is beidelite

$$\overset{\overset{Na_{0.33}}{\uparrow}}{(Al_{2.17})(Al_{0.83}Si_{3.17})O_{10}(OH)_2}.$$

(It may be mentioned here that Grim (1942) does not accept this concept of the nature of beidelite.) The aluminum in octohedral coordination may be replaced by iron as in nontronite, and this can also exist in a highly aluminous form analogous to beidelite. Manganese is also known to enter into the octohedral position in small amounts in some clays.

The expanding lattice structure of the montmorillonitic clay minerals not merely permits the entry of water and of metallic cations, but it is also known that proteins, apparently acting cationically, can enter the spaces between the layers (Ensminger and Gieseking, 1939). These properties of the montmorillonitic clays render such substances among the most remarkable of all inorganic materials known in nature. They are not in any absolute way to be regarded as dependent on the properties of the aluminum atom. Ross and Hendricks, for instance, describe an extraordinary clay from Hector, California, formally to be derived from talc by the substitution of one in nine magnesium atoms by lithium, and some hydroxyl groups by fluorine

$$\begin{matrix} Na_{0.33} \\ \uparrow \\ (Mg_{2.67}\,Li_{0.33})(Si_4)O_{10}(OH,F)_2. \end{matrix}$$

This clay has base-exchange properties but does not contain aluminum. While aluminum, therefore, is not essential, the commonest cause of lack of electrostatic balance is either the substitution of an aluminum by a magnesium atom, or of a silicon by an aluminum atom. Since the properties of the colloidal clay minerals are of the greatest importance in retaining the important biological cations, in an available form, in humid soils, and since in at least part of the hydrosphere, in small inland lakes, ionic exchange between water and mud is probably of great ecological importance, it is justifiable to regard the rôle of aluminum in the colloidal aluminosilicates as the greatest contribution of the element to the economy of the biosphere.

With regard to the genesis of the soil colloid minerals, there is considerable evidence that kaolinite and the related halloysite and metahalloysite may be formed either by the union of colloidal silicic acid or silicate ions and alumina immediately after liberation in the weathering of acid rock forming minerals, or by the resilication of gibbsite in the soil profile (Hardy and Rodrigues, 1939; Alexander, Hendricks, and Faust, 1941; and various papers quoted by the first authors. Halloysite has alternating silica and alumina sheets, but these are not joined by common oxygen atoms: there is much confusion in the nomenclature). Noll (1936) has likewise demonstrated the hydrothermal synthesis of montmorillonite in the laboratory. The nature of the parent rock plays some part in determining the nature of the colloid; alkalic feldspars usually produce kaolinite, calcic feldspars and ferromagnesian rocks usually montmorillonitic clays. In general the presence of magnesium favors the genesis of montmorillonite. Purely climatic and pedological factors are also to be considered; acid conditions usually appear to favor kaolinite production, alkaline conditions the production of montmorillonitic clays (Noll, 1936). The regional soil types thus tend to contain different quantities of the various colloid minerals, as Sedletsky (1941) has emphasized. Kelley, Dore, and Page (1941; Kelley, 1942), however, think that too much emphasis must not be placed on these generalizations and point out that the colloidal fraction of any clay present as a sedimentary rock may become incorporated into the soil of that basin. It is, however, clear that all the aluminosilicate clays represent so great a transformation of the primary aluminosilicate rocks and that so much synthesis, as opposed to mere hydrolytic decomposition, has taken place in their formation that it might be logical to treat them after, rather than before, the hydrated oxides of alumina.

Aluminum hydroxide and phosphate in soils

The existence of aluminum and ferric hydroxides in great quantities in tropical lateritic soils has long been known. Two markedly contrasted types of leaching can indeed be broadly distinguished. In the podsols of high temperate latitudes where mineral weathering is slow and organic matter accumulates, cations are removed from the upper horizons, which become poor in alkalies, aluminum and iron, but rich in silica. The sesquioxides, moving down bound to oxidisable organic colloids, are, however, redeposited at a lower level, so that part of the B horizon is very rich in alumina and ferric hydroxide. In the tropical lateritic soils in regions of rapid weathering and rapid organic decomposition, silica is removed by leaching leaving a soil exceedingly rich in alumina and often in iron also. Mattson believes that the end point of the process is determined by a tendency of the colloids of the soil to change their composition until their isoelectric point approximates the prevalent pH of the soil. No silica is bound by ferric or aluminum hydroxide above pH 7.0 and pH 8.0 respectively. A very large number of variations of this general process occur, which has been over-simplified in so brief a presentation. Further details must be sought in any adequate work on pedology, and in Mattson's (1941) paper

on the structure of the pedosphere, which paper, though written from a rather special point of view, is most illuminating and should be studied by all general ecologists.

In temperate soils the presence of the trihydrate gibbsite $Al(OH)_3$ has been postulated by various workers from time to time, but the only satisfactory estimates of its abundance are the recent determinations of Alexander, Hendricks, and Faust (1941), who find in soils from Georgia, and North and South Carolina up to 10 per cent of the dry soil or up to 33 per cent of the soil colloid may consist of this mineral. Gibbsite can be produced in weathering from a great variety of aluminosilicate minerals, and evidence was obtained that when silica was also dissolved in the same profile, a resilication of gibbsite could occur within a few centimeters of the site of solution, leading to the synthesis of kaolinite. Hydrosols of aluminum hydroxide certainly are found in soil solutions, appearing at slightly higher pH values than aluminum in ionic solution (Denison, 1922; McGeorge, 1924; Joffe and McLean, 1928b).

Mattson considers that the whole of the physical chemistry of the soil colloids is best treated in terms of a continuously varying *alfesic complex*. This is supposed to consist of aluminum and ferric hydroxides, hydrated silica, and organic matter, and to be comparable to the complexes that can be prepared artificially in which at any pH a definite amount of silica is precipitated from solution per mol of sesquioxide. By treating such a complex as an ampholytoid, i.e. as a dispersed solid bearing on its surface ionisable H^+ and OH^- groups, a number of predictions as to the behavior of soil colloids can be made and these predictions verified by experiment. Mattson (1941) supposes that the alfesic complex coats the microcrystalline particles of the clay minerals, each of which carries its own micropedosphere. It is, however, not improbable that much of his theory actually would be applicable to a continuous series of clay minerals of varying aluminum content.

The occurrence of aluminum phosphate in solid form has long been regarded as probable in acid soils. It has indeed frequently been supposed that for some plants the presence of this material is of importance, as being insoluble over a wide range of hydrogen ion concentrations, any plant that could utilize the phosphate would be in an advantageous position in an acid soil, poor in nutrients. In so far as the relationship of phosphorus and aluminum has an important bearing on the ecological significance of the latter element, the problems presented by aluminum phosphate will be discussed later in the present paper.

Ionic aluminum in the soil solution

The existence of aluminum in extracts of acid soils made with neutral salt solutions (exchangeable aluminum) was observed by Veitch (1904), Abbott, Conner, and Smalley (1913), Daikuhara (1914), Ruprecht (1915), Ruprecht and Morse (1915). It was supposed that the acidity of such soils was due to the hydrolysis of aluminum salts; Abbott, Conner, and Smalley, studying a peculiar acid swamp soil, concluded that aluminum nitrate was formed by bacterial nitrification in sufficient quantities to produce a markedly acid reaction as the result of hydrolysis. Some of the soils studied by other investigators had been treated with sulphur (Ames and Boltz, 1919; Denison, 1922) or ammonium sulphate (Ruprecht and Morse, 1915; Hartwell and Pember, 1918), both of which treatments lead to an increased acidity. Little satisfactory progress, however, was made until the introduction of the study of pH values of soils, which made possible an adequate expression of this acidity, whatever its cause. The discovery of Rice (1916) that aluminum appears in soil extracts only below pH 4.5 and the work of Hartwell and Pember (1918) suggesting that aluminum as such has an important rôle in regulating plant growth on acid soils, soon led to a large body of work on the soluble, available, or active aluminum in soils, and to much controversy as to the significance of the results obtained. Some of this work (Mirasol, 1920) was clearly inadequate technically; in other cases (Burgess, 1923b) the technique employed did not measure the most interesting quantity. Some of the criticism (Line, 1926) directed against these earlier investigations was therefore largely justified at the time, though improved experimental and analytical techniques have now clearly demonstrated that soluble aluminum does indeed play an important part in the biogeochemistry of soils. There is therefore now no need for an extended review of these first and controversial contributions to the subject; excellent summaries are given both by Line (1926) and by Hardy (1926).

In considering the more modern investigations, a distinction might be drawn between investigations that are devoted primarily to defining the conditions under which aluminum appears, and

those in which an interpretation of the mechanism of appearance and of the source of aluminum is attempted. The first approach is all that is needed in ecology, whether pure or applied; the second is required if a complete biogeochemical investigation is desired. In practice most papers have considered mainly the conditions for the appearance, but nearly all have hinted at further interpretation. It has, therefore, been found convenient to give an account of the development of the subject more or less chronologically, adding an interpretative summary at the close of the section.

The first investigation that must be examined in detail is that of Magistad (1925). Magistad first studied the solubility of aluminum hydroxide precipitated from aqueous solutions of the sulphate by sodium hydroxide at different pH values, in the absence of, or in the presence of, excess phosphate. In the absence of phosphate, appreciable quantities of aluminum were found in solution below pH 4.5 or above pH 8.0. In the presence of excess phosphate, no appreciable amounts of aluminum were found in solution above pH 4.0. These results are of course in accord with the generally accepted properties of the hydroxide and the phosphate (see also Line, 1926; Joffe and McLean, 1928a). Other workers (Joffe and McLean, 1928a; Hardy, 1926) have pointed out that even in the absence of phosphate, the nature of the anions present is of importance; not merely are complex ions formed as with citrate and oxalate, but the apparent pH-solubility curve in the presence of nitrate or chloride is markedly different from that obtained by Magistad, owing to the formation of a hydrosol.

Magistad proceeded to study the aluminum content of soil solutions displaced from the soil by alcohol. This method is undoubtedly superior to extraction with salts ("exchangeable Al", presumably in large part derived from the soil colloids) or acetic acid ("available Al" which could also include easily soluble hydroxide unassociated with any other complex), used by the earlier workers, as by such means data are obtained as to the properties of a solution, more or less approximating to that which is in contact with root hairs or soil organisms. Using a number of soil samples artificially acidified with H_2SO_4 or made alkaline with NaOH, the aluminum contents of the soil solutions of known pH were found to agree closely with those expected from the pH-solubility curve. Six untreated soils, naturally between pH 4.87 and 9.01 gave similarly concordant results, though slight divergences from the expected values were noted. Magistad therefore concluded that in the absence of excess phosphate, the aluminum content of the soil solution, i.e. the aluminum content of the immediate environment provided by the soil, is primarily a function of pH. Dialysis experiments with solutions from soils of artificially adjusted pH showed that the aluminum found was almost entirely in true solution at low pH values, largely in true solution at high values. This absence of the hydrosol, conflicting with the results of Denison (1922) is certainly due to the treatment of the soil with sulphuric acid.

Later work (Blair and Prince, 1927; Pierre, 1931; Pierre, Pohlman, and McIlvaine, 1932), while in general confirming the dependence of aluminum content on pH when similar soils or parts of the same profile are compared, has shown that the problem is far more complex than Magistad believed. As an example, it has been shown (Pierre, Pohlman, and McIlvaine) that a displaced soil solution naturally at pH 4.00 may contain from 1.5 p.p.m. Al to 27.2 p.p.m. Al. It is certain, therefore, that solubility at a given pH is not the only factor involved, and a number of contributions that elucidate the nature of other significant variables must now be considered.

Joffe and McLean (1928a) made studies of the precipitation of aluminum hydroxide from various salts. They agree with Magistad regarding precipitation in the presence of sulphate, and find that at no pH is a hydrosol formed. In the presence of chloride or nitrate, dialysable aluminum is present up to pH 5.1 and 5.9 respectively, while between pH 4.3 and 5.6 in the case of the chloride and pH 4.4 and 5.9 in the case of the nitrate, a hydrosol is formed. Joffe and McLean (1928b) found that a soil at pH 4.2 treated with ammonium sulphate for many years contained 28 p.p.m. dialysable sesquioxides and only 5 p.p.m. sesquioxides as hydrosol. In all other cultivated soils they found less than 20 p.p.m. dialysable sesquioxides, and in some cases an excess of hydrosol over the amount in true solution. They are therefore inclined to believe that the nature of the anions present is of considerable importance.

Turner (1931) studied the aluminum that can be replaced from soils by sodium from normal sodium chloride solutions, in two series of Trinidad soils of high colloid and low organic content. Exchangeable aluminum never appeared when the soil pH was from 6.7 to 7.5, and always appeared when the

pH was below 5.1. In the intermediate range the appearance was irregular. More than 0.6 milli-equivalents per 100 grams were not found above pH 4.8; below this a rapid irregular rise occurred. The amount of replaceable aluminum is well correlated with the saturation deficit (replaceable hydrogen) of the soil. No aluminum is exchanged if the saturation deficit is below 8.25 milli-eq. per 100 grams. Between this value and 15.5 milli-eq. per 100 grams the aluminum rises slowly, above 15.5 milli-eq. very rapidly. The soils with a deficit of 15.5 or more all have a pH of 5.1 or less. It is supposed that above pH 5.1 replacement of Al is indirectly by H ions that have exchanged for sodium. Below pH 5.1 direct replacement also occurs, the sodium exchanging for aluminum very much more slowly, so that leaching to more than 1 litre is needed to obtain all the exchangeable aluminum from a 50 gram sample. Correlation with the percentage unsaturation was much less good than with the absolute value. The differences between soils of different types are considered as possibly due to differences in the degree of hydration of alumina gels, from which the replaceable aluminum may be derived.

Pierre, Pohlman, and McIlvaine (1932) have made the most extensive study of the problem yet published. They found that the simple linear coefficient of correlation of soluble aluminum in the displaced soil solution on hydrogen ion concentration (expressed as such) for 26 samples of typical mineral soil, was $r = +0.854$ (given as $+0.584$ but clearly a misprint as r^2 is given as 0.729). A less significant value of $r = -0.422$ was obtained for the correlation on specific resistance, indicating a slight tendency for the aluminum to increase with increasing concentration of all ions. The rectilinear multiple correlation coefficient for the dependence on these two variables was $r = 0.877$; as would be expected, employment of a curvilinear technique leads to an improvement, the index of total correlation being $r = 0.939$. It thus appears that while the hydrogen ion concentration is the most important single factor involved, the presence of a high concentration of electrolytes also favors a high concentration of aluminum. Parenthetically it may be noted that fertilization with potash, by increasing the aluminum and iron in the soil solution, may cause immobilization of phosphorus (Eriksson, 1940). Pierre, Pohlmann, and McIlvaine found, contrary to the view of Joffe and McLean, no significant effect due to the nature of the anions. The presence of abundant organic matter, however, tends to reduce the aluminum concentration, as in the case of four very organic soils omitted from the statistical analysis. High organic matter has been observed to mitigate the toxic effects of aluminum in podzolic soils (Ganzha, 1941). Pierre, Pohlmann, and McIlvaine also believe, partly on the basis of some evidence given by Pierre (1931), that at a given low pH a soil with a relatively high percentage base saturation (ratio of replaceable bases to sum of replaceable bases and replaceable hydrogen), will have relatively less aluminum in solution than a soil with a low percentage base saturation. The evidence for this last conclusion is not convincing, and not entirely in accord with Turner's results, though the relationship may be an indirect one, explicable theoretically as indicated in the next paragraph.

The whole of the findings of Pierre, Pohlmann, and McIlvaine are greatly illuminated by the studies of Mattson and Hester (1933), though it has been previously indicated that these studies are based on a theory of soil colloids that is perhaps not now widely accepted. Mattson (1931) has shown that when soils are electrodialysed, an appreciable amount of silica is found in the material that collects at the cathode. This silica can only be transported as complex cations, such as

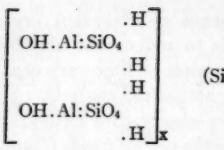
$$\begin{matrix} OH.Al^{+} & .H & & .H \\ & :SiO_4 & \text{or} & Al^{+}:SiO_4 \\ OH.Al^{+} & .H & & .H \end{matrix} ;$$

it is also probable that the aluminihydroxyl ion $Al(OH)^{++}$ is present in such solutions, Al^{+++} only appearing in appreciable quantities at very low pH values. The concentration of all such ions will be regulated not merely by the pH of the soil solution, but also by the nature of the colloidal complexes from which they are derived, which for the purposes of discussion may be regarded as amphoteric colloids formed from silicic acid and aluminum hydroxide.

An hypothetical complex of the general form

$$\left[\begin{matrix} OH & & \\ & :Al & \\ OH & & .H \\ & :SiO_4 & \\ OH & & .H \\ & :Al & \\ OH & & \end{matrix}\right]_x \qquad (SiO_2:Al_2O_3 \text{ as } 1:2)$$

having an excess of basic groups, will have its isoelectric point at a higher pH than the less basic complex



($SiO_2:Al_2O_3$ as 1:1)

At the pH of the isoelectric point of the second colloid, the first colloid will be positively charged, being on the acid side of its higher isoelectric point. The positive charge will be due to ionization of the basic groups. By hydrolytic cleavage some of the basic groups will then pass into true solution at a pH at which the second less basic colloid is stable and insoluble.

By means of precipitating aluminum hydroxide or silicic acid in electrodialysed soils and then removing the excess precipitant (either NaOH or HCl) by further electrodialysis, Mattson and Hester prepared soils with artificially varied $SiO_2:Al_2O_3$ ratios and found that the pH at which biologically significant amounts of aluminum appeared in solution was indeed regulated by the ratio. Phosphoric acid, and electrodialysed "humic acid" behaved, as would be expected, like silica in this respect. At low pH values the anions of neutral salts will displace OH ions from the basoid residues and this will increase ionization and solubility. Moreover, at a given low pH in soils with a low $SiO_2:Al_2O_3$ ratio, the relatively few replaceable hydrogen atoms will tend to remain unionised, and the soils will therefore have a low percentage base saturation.

All the correlations observed by Pierre, Pohlmann, and McIlvaine, therefore, appear to receive a formal explanation from the amphoteric colloid theory developed by Mattson, though the artificial soils used in the experimental development of the theory must be regarded as models rather than as identical with natural materials.

Menchikovsky and Puffeles (1938) have studied the effect of the various exchangeable cations on the stability of the colloidal complex, using Burgess' (1923a) "active" aluminum concentration (aluminum extracted by 0.5 N acetic acid) as a measure of stability and so of the tendency of the complex to decompose, producing the easily soluble aluminum found in many degraded Palestinian soils. Using a red loamy soil from near Jerusalem and a heavy alluvial soil from the Yarkon River on the coast of Palestine, they found high values for active aluminum when the colloids were saturated with H·, Li, and Mg··, low values when saturated with K··, Ca··, and Ba··; Na occupied an intermediate position. Except with the H·-saturated ("unsaturated") complex, the amount of active aluminum varied independently of pH; thus for the Alharoth red loamy soil:

	pH	*Active aluminum p.p.m. of soil*
Original soil	6.8	95
Saturated H·	5.6	98
Saturated Li	7.4	85
Saturated Na	7.2	35
Saturated K	6.8	24
Saturated Mg	7.3	90
Saturated Ca	7.4	25
Saturated Ba	7.4	25

It is clear that since lithium saturation would not occur in nature and magnesium saturation is rare, the percentage saturation is here of importance in regulating easily dissolved aluminum. Menchikovsky and Puffeles conclude, therefore, that the more highly dispersed lithium, magnesium, and to a less extent, sodium, colloids are more easily broken down to liberate the "active aluminum," than are the less dispersed colloids saturated with the heavier alkali or alkaline earth ions.

Most of the earlier workers appear to have assumed that the exchangeable or available aluminum of extracts or the aluminum present in soil solutions *in situ* is derived from aluminum hydroxide (Clarens and Lacroix, 1932), or, in the case of Mattson's contributions, by ionization and hydrolytic cleavage of the alfesic complex. Alten and Kurmies (1935), however, found that a specimen of montmorillonite leached free of exchangeable calcium with HCl, can exchange aluminum for potassium, and that this aluminum can be replaced stoichiometrically by ferric iron. According to Grim (1942) it is probable that in electrodialysed montmorillonites, commonly supposed to be H^+ saturated, a considerable amount of aluminum has left the lattice to occupy exchange positions between the layers. Such aluminum is presumably an important source of soluble aluminum in natural acid unsaturated soils and in the unsaturated preparations studied by Menchikovsky and Puffeles. There are obviously two possible methods by which this exchangeable aluminum might appear in neutral salt extracts. Firstly, a direct exchange of superficial aluminum with the cations of the salt might be postulated; secondly the replacement of hydrogen ions by metallic cations, lowering the pH of the solution, would permit

exchange of aluminum for hydrogen or, as a special case, the solution of aluminum hydroxide. Turner has indeed interpreted his experiments as indicating the occurrence of both processes.

ALUMINUM IN THE HYDROSPHERE

While the data available as to the soil are ample to indicate the main sources of the element from which plants, and indirectly, terrestrial animals may accumulate the element, the aluminum content both of the ocean and of inland waters is little investigated and inadequately understood. Although aluminum has been widely accepted as occurring in sea water, the only acceptable data are those of Goldschmidt (1937) who records without details 0.6 mg. per kilogram, and the more extensive results of Haendler and Thompson (1939). The latter investigators found at Friday Harbor from 0.007 to 0.024 mg. atoms or 0.19 to 0.65 mg. Al per litre. In this littoral water the mean monthly value appeared to be slightly greater in spring than at other seasons. In deep stations in the northeast Pacific there was rather more aluminum than at Friday Harbor. In general there is more aluminum below 300 m. than in the surface waters; the authors conclude there are indications of a maximum at 900–1000 m., then a decrease in concentration and another increase near the bottom. The maximum at intermediate depths is apparently associated with the zone of low oxygen and high iron at such depths, but the data are too irregular to justify any definite conclusion. The highest value reported is .065 mg. atoms or 1.76 mg. per litre at 2000 m. (lat. 48° .06′N, long. 126° .30′). The mean value of all determinations is 0.02 mg. atoms or 0.54 mg. per litre, in good agreement with Goldschmidt's estimate. Haendler and Thompson believe this aluminum to be in ionic form; at the ordinary pH values of sea-water aluminate ions are presumably present.

In fresh waters a number of isolated analyses exist, but no comprehensive study has been made. In ordinary more or less neutral waters the amount to be expected is apparently of the order of 0.1 mg. per litre, as for example in Würzburg tapwater (0.12 mg. per litre) analyzed by Lehmann (1931a); much of this may of course be in colloidal solution. It is reasonable to suppose that in acid waters considerable ionic aluminum may occur, complex aluminosilicate ions would also be expected. In extremely alkaline lakes large amounts of aluminum may sometimes be found, as Wait (1900) records 0.183 g. per kilo. Al_2O_3 in the filtered water of Lake Goodenough in British Columbia; this presumably is present as aluminate.

ALUMINUM AND THE DETOXICATION OF THE SILICA OF THE BIOSPHERE

Before proceeding to an account of the occurrence of aluminum in organisms, it is desirable to discuss briefly the work of Denny, Robson, and Irwin (1937, 1939) on the prevention of silicosis by the suspension of aluminum dust in inhaled air, for this work seems to provide evidence of a function of aluminum, external to the organism, but nevertheless of considerable biological importance.

It is well known that when air containing very finely divided silica, of particle diameter of 5 μ or less, is continuously inhaled, pathological changes occur in the lung epithelium and fibrotic nodules are produced. Local accumulations of finely divided silica, when established by subcutaneous injection, produce comparable fibrotic nodules, whereas neither elementary silicon nor a variety of dusts made from aluminosilicate minerals (microcline, albite, sericite, orthoclase, oligoclase, talc) induce fibrosis (Williams and Irwin, 1938). While a number of pathological changes resulting from the inhalation of other dusts, including aluminum hydroxide (Haynes, 1931) have been described, the injection experiments of Williams and Irwin indicate that among the naturally occurring compounds of silicon, quartz dust is unique in its biological effects. It is, therefore, hardly possible to disagree with the view that the excess negative surface charge, due to the oxygen atoms of the quartz lattice, gives to freshly broken and finely divided silica its special physiological properties. Denny, Robson, and Irwin found that metallic aluminum powder greatly reduced the solubility of quartz and that when animals were treated with mixed silica and aluminum dusts, no silicosis developed when the ratio Al:SiO was in excess of 1:100. The exact mechanism of the protective effect is uncertain; since soluble silicates do not produce silicosis, mere reduction in solubility is unlikely to be involved. Emmons and Fries (1938) believe that aluminum and other protective substances act by flocculating the dispersed silica. Denny, Robson, and Irwin found that metallic aluminum produced a film of gelatinous aluminum hydroxide around the silica particles; this on drying produces boehmite, the α-monohydrate $Al_2O_3 \cdot H_2O$. It is clear that the

adsorption of such a material will neutralize the negative charges on the particles. It has long been known that the dust from certain rocks mixed with silica gives some degree of protection. This is attributed to the presence, in dust from slates, shales, and other rocks, of hydrated alumina in a form capable of producing a film on silica particles. There is little or no evidence that dispersed silica ever occurs naturally in a toxic form in the biosphere. It is, however, clear that if the inert material of the continental shields were primarily quartz rather than aluminosilicate rocks, the possibility of the generation of natural toxic dusts would be much greater than is actually the case. Too little is known about the reaction of non-mammalian tissues to silica to permit any certain generalization, but it seems possible that the aluminum of the biosphere is the most important of a series of substances that act as detoxicants on an unprecedented and previously unsuspected scale. A somewhat similar function is discussed by Goldschmidt (1937) who believes that the continual sedimentation of fine particles of clays and of ferric and aluminum hydroxides, which have certainly had a profound effect on the concentration of the heavier alkalies in sea water, have also, by adsorbing certain of the more poisonous elements such as selenium, arsenic, lead, antimony, and bismuth, acted as detoxicants of the ocean. Fundamentally, in all these cases aluminum seems to play a part external to the organism, largely based on the crystallochemical and electrostatic properties of its ionized atom, which is in a general way comparable to the rôle of the element in the building of base exchange complexes.

THE ALUMINUM CONTENT OF PLANTS

The work of the chemical naturalists of the nineteenth century

The existence of a plant, extracts of which acted as a mordant, like alum, was known to Rumphius at the close of the seventeenth century, and was reported in his posthumous *Herbarium Amboinense* (1743). No certain identification of the element was made until considerably later. Vauquelin (1800) claimed to find aluminum in the sap of the birch, but the first reasonably certain determination is probably that of de Saussure (1804) who reported 0.12 per cent Al_2O_3 in the ash of *Rhododendron ferrugineum* L. and traces in other plants. John (1821a, b) demonstrated the accumulation of aluminum in *Lycopodium*, so definitely establishing the element as a possible component of organisms. Sprengel (1828) regarded small amounts of aluminum as a normal constituent of plants; he found that aqueous solutions of aluminum salts stimulated certain plants, notably *Canna indica*, and considered that the element may well have a functional significance in certain cases. Berthier, however, (1826) was unable to find aluminum in wood-ash, and suggested that its apparent absence in living organisms was in part related to the low solubility of alumina in water.

The remarkable paper of Sprengel (1828) is noteworthy for an early list of the biological elements, at least those taken up by plants, namely, oxygen, carbon, nitrogen, hydrogen, chlorine, sulphur, phosphorus, iodine, calcium, magnesium, aluminum, silicon, barium (in *Astragalus exscapus*), zirconium (in black pepper), potassium, sodium, iron, copper (? analytical contaminant), manganese, fluorine (by implication since it may be found in the animal body). It is interesting to consider how long it has taken to establish the physiological importance of copper, manganese and silicon; how uncertain is our knowledge of some of the others, even today.

In the middle years of the nineteenth century, a very large number of ash analyses of various plants and animals was published. This analytical activity grew in part from the rise of agricultural chemistry, and was concomitant with the extreme chemical outlook on the part of applied plant physiologists, induced by Liebig. At the same time the pharmaceutical properties of a great number of plants used traditionally as remedies in all parts of the earth were being examined. Often the pharmacologically active substances escaped the analyst, or the plant proved to have no place in a modern pharmacopeia. The more thorough investigators, however, usually included an ash analysis in their studies, and although the primary object of obtaining information of medical value might not be achieved, a large amount of data accumulated relating to species of plants, and to a lesser extent to animals also, that would not have been analyzed by agricultural chemists. Many of these agricultural and pharmaceutical chemists had wide geochemical and biological interests and their papers, now more or less forgotten, frequently contain interesting suggestions of a more general nature than might be expected from the statement of the title. In Germany, G. C. Wittstein (1810–1887) was one of the most influential of such chemi-

cal naturalists; a number of papers by Wittstein and by his students will be mentioned throughout the present review. The pages of his *Vierteljahrschrift für praktische Pharmacie* contain far more material of broad biochemical interest than would be suspected from the title of the journal. At a slightly later date, Sir A. H. Church, in England, who viewed biogeochemical problems with the eye of an art critic from a chair of agricultural chemistry, made a number of interesting contributions, some of which will be discussed at length below. Further historical investigation is needed to characterize accurately the whole contribution of this period, which gradually came to an end with the increasing importance of synthetic drugs in pharmacy, the realization of the importance of soil physics in agricultural science and the decline in the breadth of intellectual interest of the average scientific worker.

In spite of the enthusiasm and industry of this period, it is necessary to treat all the older analytical results with caution. Church's (1888b) view, that the aluminum determinations of his predecessors of the order of 1 per cent Al_2O_3 in the ash should be rejected as due to contamination, may be extreme, but it is certain that many records are invalidated by admixture of soil. Some of the best chemists freely admitted that the small quantities of aluminum detected were due to contamination and believed the element to be absent from normal biological materials. When its presence was reluctantly admitted in very small amounts (e.g. Allen, 1888), such minute quantities were usually regarded as of little interest. It is probable that the analytical methods employed frequently did not permit adequate separations of aluminum from titanium, from the alkaline earths, and from manganese, these separations being difficult to accomplish in the presence of excess phosphate, without careful control of the hydrogen-ion concentration. The greater part of the older data has been summarized by Langworthy and Austen (1904) and by Pellet and Fribourg (1907); largely on the basis of the work of the former authors, Mellor (1929) quotes almost one hundred and fifty records of the occurrence of aluminum in flowering plants. Many of these are merely qualitative; a large proportion are, as has just been indicated, doubtless invalid. Moreover, the reliable analyses may well represent a selected group, as the element may have been reported only where it had been first detected qualitatively. Such records would, therefore, be useless in determining the mean aluminum content of terrestrial vegetation as a whole. All the nineteenth century work that bears on the problem of excessive aluminum accumulation and all that might throw light on the mechanism of aluminum uptake or on the distribution of the element in the plant body has been considered. No apology is needed for the omission of the other older records which are accessible to the curious in the aforementioned reviews.

The ash analyses of Witting (1850), Staffel (1851), and Wittstein (1854, 1855b, 1862) and the special studies of L'Hôte (1887), Yoshida (1887), Young (1888), Ricciardi (1889), and Berthelot and André (1895) provided for the first time *prima facie* evidence of the existence of about 0.1 per cent Al in the ash of the spermatophytes. Witting's clearly arranged paper in the curious *Nordamerikanischer Monatsbericht für Natur- und Heilkunde* showed the effect of both intrinsic and ecological factors in the uptake of the element, for while *Betula* was found to contain more aluminum than *Fagus*, the only specimen of birchwood in which an appreciable quantity of the element (1.38 per cent Al_2O_3 in ash) was found was one from Iceland, growing on soil said to be rich in aluminum in an available form. Staffel, and Wittstein (1854, 1862) provide what are still possibly the most reasonable estimates of the aluminum content of wood. Wittstein (1855b) in an interesting paper on the chemical composition of *Calluna vulgaris*, with special reference to manganese accumulation, records also 0.272–0.446 per cent Al in the ash; he discusses the validity of this and of his previous records of the element and concludes that, since he had evidence that the aluminum was not derived from the vessel used in ashing, it must have been an integral part of the plant. The special studies undertaken somewhat later in the century are best discussed in the next section, along with more recent contributions.

The normal aluminum content of Spermatophytes and of the terrestrial vegetation of the earth as a whole

Much of the special work (e.g. L'Hôte, Young, and many later authors) on aluminum has been undertaken to provide standards by which alum adulteration of foodstuffs might be recognized, and to ascertain the amount of the element consumed in a normal human diet. This preoccupation with edible plants must be remembered when an at-

tempt is made to assess the quantity of aluminum present in living organisms as a whole. In general, estimates based on edible parts of plants will tend to be too low. Yoshida (1887) who investigated several Japanese crop plants, growing on soil that might reasonably be regarded as favorable for the absorption of aluminum, found a mean value of 0.069 per cent Al in the ash; analyzing the grape vine, orange trees and other cultivated plants in Italy, Ricciardi obtained values, the mean of which is 0.144 per cent Al in the ash. These figures are clearly comparable to those of later investigators. Dambergis (1898) gave data for aluminum in a number of samples of Greek tobacco, finding essentially similar amounts to that recorded by the two previous workers. Pellet and Fribourg (1905a, b) who made an extensive study of the procedures used to determine aluminum in plant ash, published few determinations; they report 0.03–0.05 per cent Al_2O_3 in the ash of sugar beet and a trace in sugar cane.

The first extensive collection of data for many species of plants is due to Berg (1913) who gives numerous aluminum determinations in a work on the composition of human foods. Berg's figures range from a trace, i.e. <0.0003 per cent Al in potatoes, saboy, brussel sprouts, etc., to 0.0047 per cent of the wet weight in green cabbage. Most of the fruits are very low, containing from less than 0.0001 per cent to 0.0004 per cent. Some nuts, with much dry matter, fall in the upper part of the range. Taking the vegetables alone as reasonably representative of whole plants, the mean of twenty-six samples is 0.0018 per cent of the wet weight which corresponds to about 0.02 per cent of the dry weight. These figures are in very close agreement with those given later, but would be of greater value if some indication of analytical technique had been given.

Myers and Voegtlin (1914) examined a number of vegetable foods; they report, on a dry basis, from 0.074 per cent Al in the specimen of wheat poorest in the element, to 0.428 per cent Al in millet. Some processed foods contained even more of the element. These values are extremely high, comparable to those obtained for the aluminum in the ash of such specimens, by other workers (e.g. Yoshida, 1887; Levy, 1931). Myers and Voegtlin attempted to separate the aluminum into water soluble, acid soluble, and insoluble fractions; the results of such a separation would be of greater interest if more reliance could be placed on their determinations.

The work of Robinson, Steinkoenig, and Miller (1917) who studied forty-five whole agricultural plants, grasses, trees, and bushes, provided for aluminum, as for other elements, a very significant body of data. Though the authors determined aluminum by difference, their gravimetric method was adapted to correct for the presence of titanium and for the precipitation of magnesium and manganese along with aluminum. Due care was taken to reject contaminated material and they believe that the results are not consistently too high. These results are reported on the basis of percentage of the dry weight, and, if cases of known contamination are omitted, range from no aluminum in one sample of white clover (*Trifolium repens* L.) and in the stem of a white birch (*Betula populifolia* March) to 0.134 per cent in the needles of the short-leafed pine (*Pinus echinata* Mill.). The latter high value is, however, not characteristic of all pine needles (Karmrodt, 1864; Levy, 1931). The mean of all the analyses reported by Robinson, Steinkoenig, and Miller is 0.0287 per cent of the dry weight; if only woody tissues are considered, the mean is 0.0264 per cent of the dry weight. The dried tissues of herbaceous plants (0.025 per cent) appear to contain about the same quantity of aluminum as do the woody parts of trees, but less than the leaves of the latter.

A rather curious group of data exists, emanating from Knight's laboratory at Cornell College, Mt. Vernon, Iowa, giving the ash analyses of the fruits of various plants, mostly native North American shrubs, growing under natural conditions (Poyneer and Duffin, 1909; Lott, 1909; Gilchrist, 1909; Reed, 1909; Gouldin, 1909; Blake, 1909; Wilcox, 1910; Neidig, 1910; Sheets, 1911; Gillette, 1911; Anderson, 1911; Rayner, 1912; Dawson, 1912; Smith, 1913; Armstrong, 1913; Carhart and Miller, 1913; Marston, 1914; Slippy, 1915; Hehner, 1917; Shippee and Fodge, 1918). These analyses report aluminum as present in every sample save one, namely that of the Red Bearberry, *Arctostaphylos Uva-ursi* (L.) Spreng. The highest values are 24.01 per cent Al_2O_3 in the ash of the "fruit" of *Rosa* sp., and 27.83 per cent Al_2O_3 in the ash of the fruit of *Viburnum dentatum* L. The means for all uncultivated berries are 6.63 per cent Al_2O_3 in the ash or 0.320 per cent in the air-dried fruit, corresponding to 0.169 per cent Al in the latter material. These values are so high that they raise doubts

as to the technical reliability of the analyses, which doubts are perhaps increased by the very high sodium contents reported. One record, namely that for *Rosa* sp. by Gouldin, appears to be confirmed by Vasterling (1922). Hutchinson and Wollack (1943), however, found less than 0.5 per cent Al_2O_3 in the ash of the receptacles of three species of wild roses from Connecticut, nor could they find any evidence of the massive quantities of alumina recorded by Blake in the ash of the fruits of *Viburnum dentatum* and by Gillette in those of *V. Lentago* L., the new analyses of the former species giving 0.22 per cent Al_2O_3 in the ash, of the latter 0.09 per cent. The highest contents of aluminum reported from Knight's laboratory being unconfirmed, it seems doubtful whether any of the long list of analyses by his students can now be regarded as of interest; the results of this group of workers have, therefore, not been considered further in the present contribution.

Bancroft (1814) writes (p. xxviii–xxix) "Professor Woodhouse, of Philadelphia, supposes himself to have discovered alumine in the very acerb fruit of the diospyros virginiana, or persimmon tree." This fruit likewise proved not to contain appreciable aluminum. Bancroft suggests there may be a mordant in the berries of scarlet sumach, as an extract dyed broadcloth without alum and "the savage tribes of North America" used these berries to color feathers and porcupine quills.

Stoklasa (1922; Stoklasa, Šebor, Zbodnický, Týmich, Horák, Němec and Cwach, 1918a) has published a large number of determinations of the aluminum content of plants, and has drawn from his results certain far-reaching conclusions as to the rôle of the element in the biology of certain organisms. He gives no certain indication of the technique employed in his analyses and Levy (1931) has supposed that he used some modification of the Behrens reaction for the qualitative detection of aluminum by the formation of caesium alum, in his quantitative studies; the reaction, however, cannot be applied quantitatively. From Stoklasa's statement, repeated in both his contributions, that alumina, iron oxide, and phosphate were determined, it would seem probable that the method employed was the orthodox precipitation of ferric and aluminum hydroxides and phosphates with ammonia, after which the alumina may have been determined by difference. Whatever technique may actually have been employed, it is possible that it was too crude to give reliable results.

Stoklasa's data are presented in two main series, one for xerophytes, the other for hygrophytes and hydrophytes. Considering only seed-plants, for which analyses of both roots and aerial parts are given, the xerophytic series is found to comprise a number of plants containing only a trace of aluminum, while the maximum amount encountered was 0.33 per cent Al in the ash of the root of *Spergula arvensis* L., or 0.016 per cent of the dry matter of both roots and aerial parts of *Saxifraga granulata* L. Taking the entries for a trace as zero, the mean aluminum contents for the xerophytic plants analyzed are:

	Per cent Al ash	*Per cent Al dry matter*
Aerial parts	0.081	0.0030
Roots	0.147	0.0037

These figures are not discordant with those of other investigators, though, doubtless owing to the treatment of the entries of a trace as zero, they are lower than most means that can be derived from published data for dry matter. In the series of hygrophytes and hydrophytes, the aluminum content is uniformly higher; in none of the forty-one species of spermatophytes in these ecological categories is the aluminum content of the ash as low as in the equivalent parts of any of the thirty-one xerophytes, while there is hardly any overlap if dry weights are considered, only *Saxifraga granulata* L. exceeding four hygrophytes. The minimum values for the roots of hygrophytes are 1.37 per cent Al in the ash of the root of *Pedicularis palustris* L. or 0.055 per cent in the dry matter of the roots of *Oxalis Acetosella* L.; and for the aerial parts, 0.164 per cent of the ash of *Caltha palustris* L. or 0.0096 per cent of the dry matter of *Pedicularis palustris*. The means for the thirty-six hygrophytes, for which analyses for roots and aerial parts are given separately are:

	Per cent Al ash	*Per cent Al dry matter*
Aerial parts	0.93	0.057
Roots	3.43	0.326

Omission of the very high values for the roots of *Scirpus maritimus* L. and *Rumex maritimus* L. would only reduce the root ash value to 3.09 per cent. Some of the hygrophytes are stated to accumulate very great amounts of the element the ash of the root of *Scirpus maritimus* containing 19.7 per cent, while in certain hydrophytes analyzed entire, equally high or even greater values

are recorded. This sharp distinction between the ecological groups of plants and the greater tendency for the element to accumulate proportionately in the roots of hygrophytes, naturally appeared to be of the greatest importance to Stoklasa, and if it could be established, such an attribution of significance would certainly be justified. Unfortunately the work of other investigators has cast grave doubt on the validity of Stoklasa's analytical results. Lehmann (1931a) found 0.0284 per cent Al in the dry matter of *Fucus vesiculosus*, while Meunier (1935) analyzed a number of species of attached marine algae, obtaining a rather uniform set of figures, of which that for *Fucus vesiculosus*, namely 0.0098 per cent Al in the dry matter, is the highest. Stoklasa, however, also analyzed seaweeds and found for this species 0.590 per cent Al in the dry matter, and for a number of other attached algae gave a rather uniform set of figures, all consistently fifty to one hundred times as great as those of Meunier. Stoklasa found for *Carex vesicaria* L. 0.088 per cent Al and for *C. sylvatica* (Hudson) 0.061 per cent Al in the dry matter. Levy for an undetermined hydrophytic *Carex* sp., obtained but 0.0032 per cent Al in the dry matter, which is well below Stoklasa's range for hygrophytic seed plants. Stoklasa's data would, moreover, indicate that the *Zosteraceae*, *Potamogetonaceae*, and *Ruppiaceae* are among the marked plant accumulators of aluminum, containing 7.46–12.27 per cent Al in the ash or no less than 1.38 to 2.45 per cent in the dry matter. The last figure, derived from *Ruppia maritima*, is exceeded only by a few *Diapensiacea* and *Symplocaceae*. Yet long ago Baudrimont (1862) found but 0.14 per cent Al in the ash or 0.032 per cent in the dry matter of *Zostera marina*, and Sestini (1874) but a trace in the ash of *Posidonia oceanica*, although both are plants which Stoklasa claimed to be accumulators of aluminum. Schuette and Alder (1927) record 0.122 per cent of the dry weight of mixed *Potamogeton* spp. to be Al and suspect that this was derived from contaminating mineral matter. Hutchinson and Wollack (1943) were unable to detect more than a trace of aluminum in three (*Potamogeton natans* L., *Ruppia maritima* L., and *Zostera marina* L.) of the four members of these families studied by Stoklasa. The most natural explanation of the great differences observed between Stoklasa's results and those of other workers is that his alumina determinations were made by difference and that in obtaining the mixture of hydroxides and phosphates by precipitation with ammonia, a considerable amount both of silica and alkali earth phosphates was also included. Whatever the origin of Stoklasa's results, the discrepancies that arise when they are compared with the equivalent analyses of other authors, and the fact that Levy found, even in a small series of xerophytes and hydrophytes, a complete overlapping of the range of values, make it impossible to accept his data. It must, however, be admitted that such systematic variations in correlation with the water relations of the plant, are hard to explain merely on the basis of accidental variations in erroneous analyses.

Keilholz (1921), determining aluminum colorimetrically with alizarin, obtained very low values, namely 0.05 mg. per kilo. wet weight for the leaves of *Hedera Helix* L. and 0.04 mg. per kilo. in leaves of *Prunus Laurocerasus* L. In the former plant Block (1888) had recorded 0.039 per cent in the dry leaf and rather less in the stem and root. Keilholz also concluded that mammalian tissues lacked aluminum entirely, but this has since been adequately disproved, for a number of investigators have found as much as, or more than, he found in plants, in all the tissues of the rat, dog and man. Underhill and Peterman (1929a) have pointed out that the method employed gives results that are too low; and these excessively small values for plants are, therefore, to be dismissed as erroneous.

Underhill, Peterman, Gross, and Krause (1929b), using another modification (Underhill and Peterman, 1929a) of the alizarin method, have determined the aluminum content of various vegetables and fruits; the material analyzed was chosen more to ascertain the quantity of the element in the diet of man than its distribution in the vegetable kingdom. The mean of their results is 0.00103 per cent of the fresh weight. This alizarin technique gives too high results when applied to animal tissue (Eveleth and Myers, 1936a), so that the status of this value is uncertain.

A more extensive series of vegetable foods was analyzed by Winter and Bird (1929) using another and doubtless superior colorimetric method, involving aurinitricarboxylic acid (aluminon). Omitting various unrepresentative materials, mostly cereals, and taking first the mean for each tissue and then for each species, the grand mean of their results for the whole or large parts of eight species of plants is 0.00095 per cent Al in the wet weight

or 0.00834 per cent in the dry. This includes certain plants that they believe to be contaminated, such as lettuce, beet and carrot, in which species the leaves are rich in aluminum and are also hard to clean. The mean of four carefully peeled and cleaned tissues, certainly free from appreciable contamination was, however, identical, namely 0.00095 per cent wet weight.

Levy (1931; Bertrand and Levy, 1931) studied tissues of seventy-seven species and varieties of wild and cultivated plants. She used a gravimetric method, namely a modification of the Chancel-Carnot method in which the aluminum is precipitated and weighed as phosphate. Control determinations in the presence of magnesium indicated the reliability of the method. The ranges of her data for the seed-plants are:

0.3 mg. per kilo. fresh (*Pisum sativum* L., small fresh seeds) to 78 mg. per kilo. fresh (*Solanum tuberosum* L., untuberised root).

1.0 mg. per kilo. dry (*P. sativum* as above) to 1,100 mg. per kilo. dry (*S. tuberosum* as above).

30.0 mg. per kilo. ash (*P. sativum* as above) to 15,400 mg. per kilo. ash (*Allium Cepa* L. whole onion bulb).

The mean values for the angiosperm tissues studied by Levy, namely

0.00127 per cent wet
0.00743 per cent dry
0.1036 per cent ash

are comparable to those obtained by Underhill and his co-workers, and by Winter and Bird; the ash figure is practically identical with the mean of 0.069 per cent and 0.144 per cent to be derived from the old work of Yoshida and Ricciardi respectively. The figure for the aluminum content of dry tissue is, however, distinctly lower than that obtained by Robinson, Steinkoenig, and Miller. If, however, only the figures given by Levy relating to whole plants or to plants of which enough representative tissues were analyzed to permit calculation of a mean for the whole plant be considered, Levy's grand mean is raised to 0.0203 per cent dry weight, corresponding to 0.0021 per cent wet weight. Owing to the omission of samples of seed and other unrepresentative but edible parts, it is easily understood that this more acceptable mean should be higher than those of Underhill and co-workers and of Winter and Bird.

Lehmann (1931a) analyzed fifteen samples of edible portions of plants, using a method involving the isolation of aluminum quinolate. For some of his determinations, a correction was necessary for aluminum derived from Jena glass vessels used; in other cases the analyses were done in quartz. For dry material, his results range from 2.8 mg. per kilo. in the fruit of the orange to 60 mg. per kilo. in cabbage and brussel sprouts. The mean value is 28.8 mg. per kilo. or 0.00288 per cent. The mean value for the content in nine fresh specimens, ranging from 0.48 mg. per kilo. in the orange to 9.4 mg. per kilo. in potatoes is 4.93 mg. per kilo. or 0.000493 per cent. This extremely low value is undoubtedly due primarily to the selection of the material. Lehmann gives a table of analyses showing the amount of aluminum found by other authors (older analyses collected by Langworthy and Austen, 1904; Berg, 1913; Myers and Voegtlin, 1914; Gray, 1924; Massatch, 1929; Underhill, Peterman, Gross, and Krause, 1929b; Winter and Bird, 1929; Bertrand and Levy, 1931), which show that apart from the data of Myers and Voegtlin, most of the results are of the same order of magnitude, though they give little or no indications of constant specific differences in the aluminum content of cultivated plants. The mean of the analyses by Levy of 9 plants also analyzed by Lehmann is 43 mg. per kilo. dry and this value is more than doubled by one entry for Savoy cabbage of 232 mg. per kilo. dry. Without this latter figure, the mean would be 19.4 mg. per kilo. These figures are of the same order of magnitude as Lehmann's mean of 28.8 mg. per kilo. dry and are very much lower than the 74.3 mg. per kilo. for the whole of Levy's series, let alone the mean of 203 mg. per kilo. dry here believed to be the best figure for herbaceous vegetation that can be derived from her data.

Shorland (1934) has made a study of aluminum in New Zealand pasture grasses, largely introduced species. In his analyses based on carefully brushed and washed material, the quantity of aluminum present ranged from 0.003 per cent of the dry weight in cocksfoot to 0.08 per cent in one specimen of mixed pasture grasses. The latter value was from one of four samples from Morton Mains, which were all harder to clean than the rest of the material and so may not have been freed from contaminant material. The mean of all these samples is 0.0167 per cent Al in the dry matter; if the Morton Mains samples are

omitted, the mean is 0.0076 per cent Al in the dry matter. Shorland also analyzed certain Gramineae and Legumes, separating the various parts of the plant. These separate parts appear to have been carefully cleaned. The results range from 0.0013 per cent dry matter in bamboo stems to 0.060 per cent in the roots of rye grass. Taking first the mean of the parts for each species, and then the mean for the whole set of species, we obtain a value of 0.0162 per cent Al in the dry matter. The higher value for this series is doubtless due to the presence of roots. These latter organs are certainly harder to clean than are leaves and stems, but as Shorland's roots were scraped and analyzed without the cortical layers, it is reasonable to suppose that his results are valid. As is indicated below, most authors find more aluminum in the roots, than in other structures. The value of 0.016 per cent dry matter is somewhat lower than the results of Robinson, Steinkoenig, and Miller or than the mean of Levy's restricted series. This may be due to the fact that in two species no roots were analyzed. Shorland points out that aluminum separated during the process of removing silica in the initial stages of the analyses was not included in his figures. This is presumably justifiable, and is probably a general analytical practice; it is reasonable to suppose that such alumina is largely derived from contaminant aluminosilicates.

A few determinations by Meunier (1935), who used a nephelometric method involving cupferron, may be mentioned; these relate to edible parts of plants and are therefore comparable to the results of Winter and Bird, or Lehmann. The mean is 0.0053 per cent dry weight.

Yoshii and Jimbo (1932) have made an extensive microchemical and so qualitative study of the leaves of a number of plants by means of alizarin. Their lowest category of positive results corresponds, in a short series of quantitative determinations, to 0.6–1.4 per cent Al in the ash, just overlapping Levy's series. Of the 674 species of plants, only 42 contained enough aluminum to give the test. This figure, moreover, is too high as an estimate of the abundance of aluminum accumulators among terrestrial plants as a whole, for a disproportionate number of species of *Symplocos* and of the *Theaceae* are included. In general it seems that their studies give little reason to believe that the average content of leaves is much, if any, above Levy's mean. Aluminum in amounts sufficient to give a positive reaction was found only in plants of 15 of the 121 families studied.

Monier-Williams (1935) examined a few plants, studied by previous authors, and concluded that even the best of his predecessors had cleaned their material inadequately. He concluded that properly cleaned coffee beans, and peeled potatoes, contained none of the element and lettuce but 0.34 mg. per kilo. fresh.

De Rubies and Lemmel (1935) investigated a number of wood ashes from Fernando Po, and from the Iberian Peninsula, using a semi-quantitative spectrographic technique. Aluminum was noted in seven out of ten of the tropical specimens, the amount present not exceeding a concentration of the order of magnitude of 0.01 per cent of the ash. In the material from the Iberian Peninsula, aluminum occurred in seven out of fifteen specimens, in three the concentration being of the order of magnitude of 0.01 per cent, in three others of the order of magnitude of 0.1 per cent; in one, namely *Taxus baccata* L., rather less than 1 per cent was found. These figures probably imply an average concentration in the living tree of less than 0.001 per cent. It is probable that all the wood ashes studied in these investigations were derived from larger trees than the specimens studied by Robinson, Steinkoenig, and Miller, and all may well have been growing on less acid soils than were the American plants analyzed by the latter authors.

In the recent study of Brunstetter, Myers, Wilkins, and Hein (1939) in which aluminum was determined spectrographically in a number of grasses and legumes, the high values (mean 0.10 per cent Al in dry matter) were attributed to contamination. Brunstetter and Myers (1941) found a mean of 0.042 per cent Al, a range of 0.025–0.14 per cent Al, in the dry matter of grape leaves. The mean of three varieties studied extensively are concordant (0.041, 0.045, 0.048 per cent) but the coefficient of variance high. These means are not unreasonable and not improbably overlap the range given for the ash of grape vines by Ricciardi, though Rotondi (1878) obtained lower values of the order of 0.01–0.07 per cent of the ash of the branches of the European grape vine.

Shear (1938) determined manganese, iron and aluminum in eight species of annuals grown in flower gardens. These plants had been cultivated on soils at different pH values. Shear's results for aluminum in the whole plant are high, the means for each species lie between 0.032 per cent Al

(*Ricinus communis* L) and 0.137 per cent Al (*Ageratum mexicanum* Sims) in the dry matter. The grand mean is 0.088 per cent Al in the dry matter, corresponding to about 0.009 per cent in the living plant. No difference in aluminum contents is apparent when material cultivated below pH 5 is compared with material cultivated above pH 7. Shear clearly is somewhat doubtful about the validity of these aluminum figures which are so much higher than other recent determinations.

In order to obtain a mean value for the terrestrial vegetation of the earth, the data for complete plants of Robinson, Steinkoenig, and Miller (0.025 per cent dry weight), of Shorland (mean of parts, 0.01 per cent dry weight), and of Levy (restricted series, 0.020 per cent dry weight) alone are sufficiently representative of whole herbaceous plants, those of Robinson, Steinkoenig, and Miller and of de Rubies and Lemmel of the woody parts of trees. For herbaceous plants it is clear that the correct value is about 0.020 per cent of the dry weight. Levy's restricted series contained about 90 per cent water, but is possibly overweighted in favor of tissues of high water content; an estimate of the order of 0.002 per cent Al in the living plant, is, however, as satisfactory a value as can at present be obtained. The data of Robinson, Steinkoenig, and Miller suggest that dry wood contains a proportion of aluminum comparable to dry herbaceous plants. The water content being less, the aluminum content of the live tree might be taken as 0.01 per cent. The spectrographic data of de Rubies and of Lemmel point in entirely the opposite direction, suggesting that the data derived from herbaceous plants are too high for terrestrial vegetation as a whole. In view of these contradictory findings as to woody plants, it seems best to consider the mean aluminum content of terrestrial plants as provisionally that given by herbaceous species, namely 0.002 per cent of the living plant. As has been indicated above, Monier-Williams would regard even this low estimate as probably excessive. Some old records (Staffel, 1851; Wittstein, 1854, 1862) which, unlike many of the earlier determinations, do not appear to be excessively high, indicate the Al_2O_3 content of wood ash to vary from 0.124 per cent in *Finus montana* var. *Pumilio* Willkomm to 0.92 per cent in some specimens of *P. silvestris* L.; the mean of these is 0.49 per cent of the ash, the mean ash content of the dry wood 0.96 per cent. The aluminum content of the dry wood, therefore, is about 0.0025 per cent. This would correspond to 0.001–0.002 per cent in the living tree, and is not out of harmony with the estimate here given. As is indicated below, the exact value must depend on both the specific composition of the flora of the earth, and on the quantitative distribution of hydrogen ion concentration and other properties in terrestrial soils. A number of euryionic plants mentioned in the following pages, accumulate small amounts of aluminum when growing on acid soils, and it is possible that a number of unanalyzed acidophil species will ultimately be found to contain more than normal quantities of the element.

Aluminum accumulators among the Spermatophytes

Although the usual content of aluminum found in the seed plants is low a considerable number of cases is recorded in which there is a marked accumulation of the element. The known cases of presumptive accumulators are summarized below; in general, only records of more than 5 per cent Al_2O_3, or 2.5 per cent Al in the ash are admitted, and only when it may be presumed that accumulation occurs throughout the plant, no cases being included on the basis of the roots alone. Such organs are clearly more easily contaminated than are other parts of the plant. The significant cases of root accumulation are, however, reviewed later. Some qualitative indications of high aluminum content have been considered sufficiently definite to merit consideration, for while certain of the quantitative determinations are exceedingly dubious, a few of the qualitative observations are of considerable interest. As has been previously indicated all Stoklasa's results, in the absence of adequate confirmatory evidence, have been rejected, as have those analyses of fruits emanating from Knight's laboratory. An analysis of rhubarb, quoted from Maul by Wehmer (1929) under *R. palmatum* L., as indicating 7.9 per cent Al in the ash or 1.49 per cent in the dry aerial parts, is also excluded, as Wehmer states there is clearly an error in presentation and both Brandes (1853) and Levy (1931) record low values for several cultivated forms of *Rheum*. The more noteworthy and certain groups of accumulators are marked with an asterisk (*). Every case might well be made the subject of further research.

The following arrangement of the families is according to J. Hutchinson: *The Families of Flowering Plants* (1926, 1934).

Monimiaceae

Kibara calyptrocalyx F. Muell.

Hutchinson and Wollack (1943) in a study of the supposed correlation of the color of the dried leaf and its aluminum content, found 5.0 per cent Al in the ash or 0.26 per cent Al in the dry matter of the leaf of this Australian plant.

Caryophyllaceae

Cerastium arvense villosum (Muhl.) Holl. and Brit.

Wherry (1932) finds 3.18 per cent Al in the ash of this obligate magnesium plant. The old record of 18.58 per cent Al_2O_3 quoted by Wherry from Hollick and Britton (1887) refers to mixed sesquioxides.

Proteaceae

**Orites excelsa* R. Br.

Maiden and Smith (1895) and Smith (1904) have reported a remarkable accumulation of aluminum in this Australian tree, popularly known as the "silky oak" and first erroneously identified as *Grevillea robusta* A. Cunn., to which the same vernacular name is applied. The wood contains but a small proportion of ash (0.639–0.706 per cent) but in this ash there is a quite extraordinary amount of aluminum, from 36.04–79.61 per cent Al_2O_3 being present in four specimens analyzed. The mean aluminum content of the anhydrous wood is 0.174 per cent, probably corresponding to about 0.1 per cent of the living tree. In the specimen richest in the element, a large amount of a white deposit of a practically pure aluminum basic succinate, $Al_2(C_4H_4O_4)_3 \cdot Al_2O_3$ was found in a central cavity in the trunk; from the less pure parts of this deposit, butyric acid could also be obtained. Smith regards the aluminum basic succinate as an excretory product, deposited when the tree had taken up an excess of aluminum. In the ash, the element is partly present as potassium aluminate. Some butyric acid is known to occur in the sap of *Grevillea* and of other *Proteaceae*, as well as in *Orites;* it is possible that the aluminum in the last named is transported as aluminum butyrate; no aluminum, however, was detected in the ash of three species of *Grevillea* studied.

*Theaceae

Camellia japonica L. var. *hortensis* Makino.

Yoshii and Jimbo (1932) report 2.6 per cent of the ash or 0.17 per cent of the dry plant to be aluminum. Qualitative indications of a like amount are given for var. *spontanea* Makino.

C. Sasanqua Thunb.

The same authors report 4.4 per cent of the ash or 0.26 per cent of the dry plant to be aluminum. Qualitative indications are given of a like amount in *C. reticulata* Lindl.

Eurya japonica Thunb.

Von Faber (1927) found no less than 24.1 per cent of the ash of the wood of a specimen from Javanese solfatara soil, and in Japan, Yoshii and Jimbo report 4.9 per cent in the ash or 0.31 per cent in the dry leaf to be aluminum. A comparable amount is qualitatively indicated in the leaf of *E. emarginata* Makino, but in that of *E. ochnacea* Szysz. only 0.6 per cent of the ash or 0.037 per cent of the dry material was aluminum.

Stewartia pseudocamellia Maxim.

Yoshii and Jimbo report 3.6 per cent of the ash or 0.32 per cent of the dry weight to be aluminum. Qualitative studies suggest a like content in *S. monadelpha* Sieb. and Zucc., but rather less in *S. serrata* Maxim.

Thea sinensis L.

Yoshii and Jimbo find 2.7 per cent of the ash or 0.24 per cent of the dry weight to be aluminum. Levy, presumably working with material bought in a Parisian grocery, finds but 0.877 per cent of the ash or 0.0465 per cent of the dry tea, to be aluminum. Robinson (1938), however, quotes K. C. Hou as finding 1.75 per cent Al_2O_3, i.e. 0.93 per cent Al in tea leaves.

Pentaphylax euryoides Gardn. and Champ.

Hallier (1922) states that material from Hongkong was examined in van Itallie's laboratory, and found to contain aluminum, though in less quantity than in *Symplocos fasciculata*, studied concurrently.

It would appear, as Yoshii and Jimbo insist, that aluminum accumulation is very general, though probably facultative and certainly not universal, in the family; they obtained no qualitative evidence of aluminum in *Schima* or *Ternstroemia*. A gravimetric determination of the aluminum content of *Ternstroemia japonica* Thunb. indicated that this plant contains but 0.1 per cent of the ash

or 0.007 per cent of the dry weight as aluminum, and so less than their micro-chemical method is able to reveal. The considerable variation noted for *Thea* may well be due to variations in soil acidity (Robinson, 1939).

*Melastomaceae

In a letter written from Pondichery on 13 October, 1748, by Père Coeurdoux, S. J., and later published in the *Lettres édifiantes et curieuses* of the Jesuit Fathers, an account is given of the use of the leaves of the *cacha* (*Memecylon edule* Roxb. = *tinctorium* Koen. ex Willd.) by dyers in southern India, as part of a process in which no alum was employed. Roxburgh (1832) later remarked that the leaves of this tree are "an ingredient in the dyes of Coromandel." This Indian practice, in which supposedly no mordant was employed, gave rise to considerable controversy, discussed in detail by Bancroft who, though he knew of the *Decadia aluminosa* of Louriero (i.e. *Symplocos*), never realized that an alum mordant derived from a plant was actually employed. Heyne (1814) discussed the process, and implied that different localities yielded specimens differing in mordanting power. He was informed that the "nunna root (*Guilandina umbellata*)" can be used in the same way. This presumably refers to a species of *Caesalpinia*. Inspired by the account given by Père Coeurdoux, Driessen (1902) obtained material of the plant from Madura and found it to contain aluminum in considerable quantity. Treub (*fide* Driessen, *in litt.;* Hallier 1922) is said to have been cognizant of a like accumulation in *M. floribundum*. *M. ovalis* Sm. is used as a mordant in the Philippine Islands (Brown, 1921). The following quantitative data are available for the leaves of members of the family, which appears to contain relatively few species that do not accumulate the element.

Melastoma setigerum Blume.

Von Faber (1925, 1927) finds 7.08 per cent Al in the ash of this plant when growing on a very acid solfatara soil, but only 1.86 per cent when growing on normal soil.

Melastoma malabathricum L.

Hutchinson and Wollack (1943) find 15.2 per cent in the ash or 1.12 per cent in the dry leaf.

Miconia androsaemifolia Gris.

Hutchinson and Wollack find 20.1 per cent in the ash or 1.40 per cent in the dry leaf.

Chaetogastra sulphurea Naudin.

Hutchinson and Wollack find 5.02 per cent Al in the ash or 0.37 per cent in the dry leaf.

Memecylon edule Roxb.

Hutchinson and Wollack find 10.2 per cent Al in the ash or 0.87 per cent in the dry leaf.

Calycogonium plicatum Gris.

Hutchinson and Wollack find 1.33 per cent Al in the ash or 0.084 per cent in the dry leaf.

Conostegia procera (Sev.) G. Don. was also analyzed by Hutchinson and Wollack but unlike the other members of the family it accumulates very little aluminum; not enough material was available to ascertain the quantity of the element, but it was certainly not in excess of the quantities found in normal plants.

Tiliaceae

Elaeocarpus punctatus Wall.

Von Faber finds 20.4 per cent Al in the ash of the leaves of this species when growing on acid solfatara soil; very little aluminum appears to be accumulated on normal soils. A qualitative study of *E. angustifolius* Bl. from the solfatara soil likewise indicated a high aluminum content. Yoshii and Jimbo were unable to find the element in two unspecified members of the family, referred by them to the Elaeocarpaceae.

Sterculiaceae

Heritiera littoralis Ait.

Pieraerts (1927) finds slight evidence of accumulation in the wood, 3.03 per cent of the ash of which is aluminum; the ash of the other parts of the tree contains less than 2.7 per cent Al.

Euphorbiaceae

**Aporosa* spp. and *Baccaurea* spp.

Driessen (1902) records aluminum in the *sassa* of Java, *Aporosa frutescens* Bl., which plant is used as a mordant. The quantity was not determined, but is said to be less than in *Symplocos* spp. According to Hallier (1922), Driessen also notes (*in litt.*) that *Aporosa arborea* and the allied *Baccaurea lanceolata* (Muell.) Arg. were known to Treub as aluminum plants. These observations are confirmed by Hutchinson and Wollack (1943)

who find in *Aporosa sphaeridophora* Merr. 14.4 per cent of the ash or 2.06 per cent of the dry matter, and in *Baccaurea tetrandra* Baill. 12.0 per cent of the ash and 1.87 per cent of the dry matter, to be aluminum. These two genera belong to the tribe *Antidesmimi* but *Antidesma lucidum* Merr. was found not to be an aluminum plant, the ash containing less than 0.03 per cent and the dry matter of the leaf less than 0.0025 per cent of the element. Yoshii and Jimbo (1932) studied fifteen species of *Euphorbiaceae* qualitatively, but obtained evidence of a small amount of aluminum only in *Daphniphyllum humile* Maxim. Hallier suggests that *Cleidion javanicum* Bl., to which the name *djirak* in various combinations is applied, may be an aluminum plant.

Hydrangeaceae

Hydrangea spp.

Yoshii and Jimbo report slight accumulation in four species of *Hydrangea*. The remarkable investigations of Chenery, discussed in detail below indicate that *Hydrangea macrophylla* shows marked facultative accumulation where the available aluminum in the soil is high.

Rosaceae

Rubus arcticus L.

Bergstrand (1875) records this plant growing in a soil in Sweden, containing 0.5 per cent alum, on which ordinary cultivated plants would not grow. The ash contained 2.47–5.59 per cent Al_2O_3 and 12.6 per cent SO_3; the aluminum content of the whole plant was about 0.1 per cent. Though clearly markedly tolerant of soluble aluminum in both soil and in the plant body, the nature of this occurrence does not indicate that the plant is necessarily an obligate aluminum accumulator. Yoshii and Jimbo detected no aluminum in twenty-five *Rosaceae* studied.

Fagaceae

Quercus marilandica Muench.

Wherry records 3.12 per cent Al in the ash of the Blackjack Oak growing on acid woodland soil, and but 1.02 per cent when the plant grows on serpentine-barrens soil. The coastal plain woodland soil apparently contains no more aluminum than does the serpentine-barrens soil, but is somewhat more acid.

Quercus alba L.

Robinson (1938) similarly records 0.185 per cent Al_2O_3 or 0.098 per cent Al in the dry leaves of a tree on a very acid soil. Such a value is clearly determined by the substrate; Robinson, Miller, and Steinkoenig found but 0.020 per cent Al in another specimen. Slight facultative accumulation would appear to be indicated.

Moraceae

Morus nigra L.

Gonnermann (1919) claimed to find 1.59–2.09 per cent Al in the dry matter of mulberry leaves; these results are doubtless excessive, but Ongaro (1931) has noted appreciable quantities of aluminum in the leaves of *M. nigra*, his values ranging from 0.08 per cent Al to 0.68 per cent Al in the dry leaf, the mean content of 28 specimens being 0.36 per cent. Eighteen of Ongaro's specimens came from clay soils; in these the range was 0.12 per cent to 0.68 per cent, the mean being 0.42 per cent. On calcareous soils, from which six specimens were analyzed, the aluminum content was lower, as might be expected, the range being 0.08 per cent to 0.39 per cent, the mean 0.20 per cent; this is still sufficiently high to indicate that the plant accumulates the element in more than ordinary quantities, even from alkaline soils. Aluminum was also detected in the cell sap, most abundantly in that obtained from vascular parts. It is curious that Yoshii and Jimbo found no aluminum in the leaves of eleven Moraceae studied; the Italian mulberries must contain several per cent in the ash of the leaves.

Juglandaceae

**Hicoria ovata* (Mill.) Britton.

Robinson (1938) records 0.15–0.79 per cent Al, containing a small admixture of rare earths, in the dry leaf of the hickory, presumably of this species, which appears in favorable soils to accumulate rather large amounts of many of the less common constituents (Robinson and Edgerton, 1942). The lowest quantity of aluminum was obtained from a tree growing on a slightly alkaline limestone soil, the highest values from trees on acid polsolized soils. Hutchinson and Wollack (1943) find 9.25 per cent of the ash or 0.635 per cent of the dry matter to be aluminum in leaves of a Connecticut specimen of *H. ovata*. It is interesting to note that in the allied *Juglans regia*, Staffel (1851) found but

0.095 per cent Al in the ash of the spring leaves, 0.032 per cent in that of the autumnal, corresponding respectively to 0.0073 per cent and 0.0023 per cent of the dry matter; the bark contained rather more, namely 0.15 per cent of the ash or 0.0098 per cent of the dry matter. The walnut, unlike the hickory, clearly does not accumulate aluminum; more species of both genera should, however, be studied.

Umbelliferae

Cicuta maculata L.

Glenk (1891) records that 20 per cent of the ash of the fruit is Al_2O_3, corresponding to 0.64 per cent Al in the dry fruit or 0.58 per cent in the ripe but undried material. This record may be regarded as very doubtful. Yoshii and Jimbo studied the leaves of sixteen umbellifers qualitatively, but detected no aluminum.

*Diapensiaceae

Diapensia lapponica L.

Yoshii and Jimbo (1932) find 16.3 per cent of the ash or 0.70 per cent of the dry plant of var. *asiatica* Herd. to be aluminum. Hutchinson and Wollack (1943), analyzing somewhat withered leaves of *D. lapponicum* from Mount Washington, New Hampshire, find 23.0 per cent in the ash or 1.19 per cent in the dry plant. Since these leaves were from a plant that had died after an attempt at transplantation, the more soluble ash constituents may have in part been lost.

Shortia soldanelloides Makino var. *genuina* f. *typica* Makino.

Yoshii and Jimbo (1932) find 24 per cent of the ash or 1.58 per cent of the dry plant to be aluminum. They report qualitatively like concentrations in var. *magna* Makino and in *S. uniflora*.

S. galacifolia Torr. and Gray.

Hutchinson and Wollack similarly find 27.1 per cent Al in the ash or 0.99 per cent in the dry plant.

Pyxidanthera barbulata Michx.

Hutchinson and Wollack find 7.04 per cent Al in the ash or 0.46 per cent in the dry plant.

Galax aphyllum L.

Hutchinson and Wollack find 9.3 per cent Al in the ash or 0.48 per cent in the dry plant.

The entire family would appear to be characterized by marked aluminum accumulation, the genus *Shortia* in particular being rivaled, in this respect, only by certain species of *Symplocos* and the heterophyllous *Lycopodia*.

*Symplocaceae

**Symplocos* spp.

In the closing years of the seventeenth century Rumphius observed that in Amboina the leaves and bark of a tree locally known as *leha*, were used as a mordant in place of alum. This tree was later described in his posthumous *Herbarium Amboinense* (1743; ed. Joannes Burmannus) as *Arbor aluminosa* or Aluyn-Boom (Fig. 4).

George Eberhard Rumphius (1627–1702), *mercator senior et in Amboina Consul*, as his position is given on the title pages of his works, was one of the most accomplished naturalists of the seventeenth century. To his contemporaries he was known as the Indian Pliny. Though his contributions were mainly descriptive, he deserves a more prominent place in the history of biology than he is generally accorded. His accurate powers of observation are attested by his account of the lunar periodicity of certain *vermiculi marini*, locally called *wawo*, and now known as *Lysidice oele* Horst. For this species Rumphius gives the swarming dates, two or three days after the February–March full moon for the years 1684–1694, in his main zoological work, *D'Amboinsche Rariteit-kamer*, Amsterdam, 1705, which book, according to Sacheverell Sitwell, who pays the author a characteristic tribute in *Sacred and Profane Love* (1940) appeared also in a French edition with colored plates, the work of the illustrious Maria Sibilla Merian and of her daughter. An account of the almost superhuman fortitude and patience of Rumphius in executing his scientific work in the face of prodigious misfortune, is given by Fairchild (1930). The portrait here reproduced from *D'Amboinsche Rariteit-kamer* is an extraordinary delineation of a blind naturalist, whose almost arachnodactylous hands seem to imply a tactile taxonomy. The quadruped on the wall was suppressed in the second state of the plate, used in the *Herbarium Amboinense*, but it has not been possible to ascertain the meaning of this change.

According to Rumphius (Pars III, Liber V, Chap. XV, p. 160, Latin text):

"Amboinenses hujus arboris foliis ac cortice utuntur loco aluminis ad rubrum colorem tingendum, quod peragitur supra memoratis radicibus *Bancudu & ligno Sappan*, cunctis enim pigmentis constantiam addit, uti in ora Cormandelensi hunc in finem adhibetur herbula *Say*, praesertim si supra memorato *Caju Nenu* utantur,

tum hujus arboris folia ac cortex summi sunt usus, quorum defectu pigmentum nimis pallide rubens esset. Idem quoque cortex et folia exsiccari possunt, inque usum adservari, atque in alias mitti regiones ad tingendum."

A supposedly identical plant was mentioned as *Decadia aluminosa* Louriero by various nineteenth century authors, including Bancroft, but according to Radlkofer (1904) the *Arbor aluminosa* is probably *Symplocos syringoides* Brandt, which Hallier (1922) considers a variety of *S. ferruginea* Roxb., while Hallier suggests that *Decadia aluminosa*

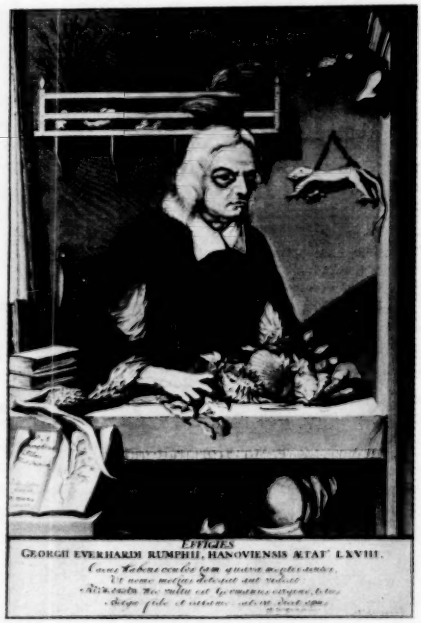


FIG. 3. GEORGE EBERHARD RUMPHIUS
(From *D'Amboinsche Rariteitkamer*)

Louriero may be *S. theifolia* Don. Roxburgh (1832) indicated that the bark of *S. racemosa* Roxb., was used in dyeing in India, though apparently in a process also involving alum. The use of *Symplocos* as a mordant became quite well known, being mentioned by various writers on Indian botany, as Stewart (1869), who says, on the authority of Cleghorn, that the bark of *S. crataegoides* Don "is employed for dyeing with madder." No adequate observations on the remarkable chemistry of these plants were, however, made until 1902, when Driessen, who had an admirable knowledge of the historical background of the subject, published a technological paper on the Oriental dye commonly called Turkey red. In this work he examined not only *Memecylon*, as has been previously indicated, but also two samples of Javanese mordant plants, both probably *Symplocos* spp., locally called *djirak* (a name also applied to *Baccaurea racemosa* Muell. Arg., to *B. javanica* Muell. Arg., and, in various modifications, to *Cleidion javanicum* Blume, *vide* Hallier, 1922), and found that they contained aluminum salts. The

FIG. 4. ARBOR ALUMINOSA
(After Rumphius)

two specimens apparently came from different species, one is stated to have been *S. fasciculata*. By comparing the mordanting action of *djirak* with that of alum solutions of known concentration, Driessen concluded that the plants, presumably air-dried, contained about 1 per cent Al_2O_3. In one specimen, a smaller plant from Batavia, the aluminum is said to have been present as sulphate, in the other, from a tree from Samarang, as tartrate. Later Driessen (*in litt.*, Hallier, 1922) indicated that Treub knew of the accumulation of the element in *S. fasciculata* Zoll., *S. spicata* Roxb.,

S. adenophylla Wall., *S. polystachya* (? = *S. ferruginea* Roxb.), and *S. odoratissima* Choisy.

In ignorance of Driessen's obscurely published paper Radlkofer (1904), while examining the histology of the South American *Symplocos lanceolata* (Mart.) A. DC. found in the leaf, mainly in the palisade cells, inorganic concretions, not destroyed by ashing, but in an unignited condition soluble in mineral acids. Similar concretions were found in *S. racemosa* Roxb., and *S. fasciculata* Zoll. Radlkofer, calling to mind Rumphius and his *Arbor aluminosa* or Aluyn-Boom, concluded that these concretions might well be formed of alumina. Chemical analysis by Hofmann, given in Radlkofer's paper, showed that 46.2–48.4 per cent of the ash of the leaf of *S. lanceolata* was in fact Al_2O_3, corresponding to 4.93 per cent Al_2O_3 in the dry leaf. Wehnert (1906) confirmed the existence of the Radlkofer bodies in a number of species of *Symplocos*, and believed them to be characteristic of the genus. Kratzmann (1913), however, was able certainly to find them only in *S. polystachya* and *S. lanceolata*. He believed that in the herbarium material of other species examined by Radlkofer and by Wehnert, comparable bodies had formed during the drying of the leaf. Neger (1923) similarly failed to find Radlkofer bodies in *S. crataegoides* Ham. though he observed them in *S. japonica* A. DC. All the species studied by Kratzmann, and, except perhaps some specimens of *S. spicata* (von Faber, 1925, 1927), by all other authors, give marked aluminum reactions, and in *S. polystachya* it was observed that such a reaction did not depend on the solution of the concretions. It is, therefore, clear that the aluminum of *Symplocos* is by no means confined to the Radlkofer bodies, but exists in solution in the cell sap whether these bodies are present or absent. Kratzmann's work also indicates that alumina is not the only constituent of the concretions. Radlkofer himself had observed that, after ashing, the bodies are insoluble in ordinary mineral acids. Kratzmann, who confirmed this, found, however, that when hydrofluoric acid was used, they immediately dissolved. It is, therefore, probable that the major constituent of the Radlkofer bodies is an hydrated silicate that is dehydrated and rendered insoluble by ashing; aluminum may well be present, but this does not appear to have been proved, though it is rendered probable from Neger's observations. The problem is of some interest, as aluminosilicates appear to be practically absent from living organisms. Neger (1923) grew *Symplocos japonica* from seed on Knopf's solution in sand culture. Four series of plants were studied, grown with the addition of no aluminum, and of 0.1, 1.0 and 10 mg. atoms Al per litre. Only in the series with 1.0 mg.-atom per litre was perfectly normal growth obtained. Such a concentration of aluminum is considerably above the maximum value that permits the best growth and development in other flowering plants. In the most concentrated solution, considerable inhibition occurred, the relative sizes of the plants in the four series being roughly as 2:2:5:1. Radlkofer bodies developed well only in the 0.1 and 1.0 mg.-atom cultures; in one of Neger's two experiments they were better developed in the lower concentration. Microchemical investigation by the caesium alum technique, however, seemed to indicate that the greatest uptake of aluminum was from the optimal 1.0 mg. per litre culture. Some aluminum could be detected even in the plants from the supposedly Al-free cultures. While it seems probable from these experiments that aluminum is required by *Symplocos japonica* and that the Radlkofer bodies play a part in the metabolism of the element, just what that part may be remains obscure. It must, however, be pointed out that no pH control was maintained in these experiments, and that the more concentrated cultures were probably significantly more acid than the controls.

Von Faber (1925, 1927) in his study of the flora of certain solfatare in Java, noted that in the very acid soils found in such localities, two species of *Symplocos*, namely *S. sessilifolia* and *S. spicata*, occurred. The leaves and roots of both species from these habitats gave abundant qualitative indications of aluminum. Quantitative studies of *S. spicata* from a solfatara soil (Kawah-Manoek) and from normal soil were made; in the former locality the plant accumulated the maximum amount of aluminum known from any organism; in the latter hardly any aluminum was found, the two records being respectively the highest and the lowest for the entire genus. A specimen from an unspecified Indian locality, hardly likely, however, to be a solfatara plant, has been analyzed by Hutchinson and Wollack (1943) and found to fall in the normal range for the genus. All the records for other species of *Symplocos* are at least ten times as great as the minimum, referred to the ash, for *S. spicata;* it is not unlikely that this species is more variable in its aluminum content than are the other members of the genus. The very low value

given by von Faber for *S. spicata* on supposedly normal soil may, however, actually refer to a specimen growing under conditions that are not really normal for *Symplocos*.

Though much of the work on *Symplocos* has been microchemical and qualitative, the following analyses have been published:

	Per cent Al in ash	Per cent Al in dry plant	
Symplocos crataegoides Ham.	13.7	1.45	(Yoshii and Jimbo)
lanceolata (Mart.) A. DC.	24.4–25.6	2.61	(Hofmann and Radlkofer)
lucida Sieb. et Zucc.	22.7	2.43	(Yoshii and Jimbo)
myrtacea Sieb. et Zucc.	27.2	3.54	(Yoshii and Jimbo)
neriifolia Sieb. et Zucc.	25.9	2.51	(Yoshii and Jimbo)
oblongifolia (Presl.) Vid.	25.5	1.75	(Hutchinson and Wollack)
polyandra (Blanco) Brand.	12.6	1.38	(Hutchinson and Wollack)
prunifolia Sieb. et Zucc.	19.2	1.90	(Yoshii and Jimbo)
spicata Roxb.	1.14–36.0	0.053–7.23	(von Faber)
spicata Roxb.	25.7	2.46	(Hutchinson and Wollack)
theophrastaefolia Sieb. et Zucc.	26.6	4.20	(Yoshii and Jimbo)
tinctoria L.	—	2.41–3.45	(Robinson)

As has been indicated above, qualitative records of aluminum or indications of mordanting action have been given for seven other species, to which may be added *S. lancifolia* Sieb. et Zucc. (Yoshii and Jimbo, 1932). Though the total number of species, for which there are indications of the element, represents but a small fraction of the whole genus, it is probably safe to regard the accumulation of aluminum as characteristic of *Symplocos*. It is, however, clear from von Faber's work that in *S. spicata* the accumulation is to some extent dependent on the nature of the soil. It is unfortunate that no data on the wet weights of the leaves of the genus have been given, but from the aluminum content of the dry material, it is reasonably certain that the specimens of *Symplocos* richest in the element contain more aluminum than do any other organisms, and that aluminum is probably exceeded in abundance only by hydrogen, oxygen and carbon in the elementary composition of such plants. Further work is needed to ascertain if the differences between various species indicated in the published data are due entirely to edaphic ecological factors, or whether there is a tendency for such differences to have a taxonomic significance within the genus, as is undoubtedly true in *Lycopodium*.

Rubiaceae

Damnacanthus indicus Gaertn. var. *major* Makino.

Yoshii and Jimbo record 6.7 per cent Al in the ash, or 0.47 per cent in the dry material. Qualitative indications of a rather less amount were given by var. *genuinus*.

Oldenlandia hirsuta L. forma.

Yoshii and Jimbo find 4.0 per cent of the ash or 0.3 per cent of the dry plant to be Al. Rather less is indicated qualitatively in *O. diffusa* Roxb.

Of the other *Rubiaceae* studied by the Japanese investigators, *Lasianthus japonicus* Miy. appears to contain abundant aluminum, *Mitchella repens* L. var. *undulata* Makino rather less. In the typical North American form of the latter plant, Hutchinson and Wollack note 1.98 per cent Al in the ash, or 0.135 per cent Al in the dry matter, and 0.0396 per cent in the living plant. Qualitative spectrographic observations indicated less in the berry than in the stem with leaves. Twenty other species of *Rubiaceae* examined by Yoshii and Jimbo gave no positive reaction; *Galium Mollugo* L. was found by Vielguth (1856) to contain but 0.16 per cent Al in ash or 0.012 per cent in the whole plant, quantities indicating no exceptional accumulation of the element. Ludwig (1872) gives some indication of accumulation in *Coffea arabica*, the coffee plant, finding in Brazilian material:

	Per cent Al in the ash
Root, young tree	4.16
Root, old tree	0.84
Leaves	4.82
Pulp of pericarp	trace
Seed coat	2.22
Bean, on gneiss soil	1.47
Bean, on limestone soil	trace

Ludwig regards at least the quantity in the leaves as significant. Levy found in coffee beans 0.1258 per cent Al in the ash; the source of the material not being specified. There is clearly a tendency in

certain species of the family to accumulate aluminum, though the majority doubtless do not.

Polemoniaceae

Phlox subulata L.

Wherry (1932) records from 2.74 to 3.56 per cent Al in the ash. Unlike other plants that he examined, the aluminum content is little lower on the serpentine-barrens than on normal acid soils.

Bromeliaceae

Tillandsia usneoides L.

Reiche (1907) found, in the ash of Chilean specimens of Spanish Moss, 9.63 per cent Al, corresponding to 0.97 per cent in the dry plant. Over half the ash was silica and the aluminum exceeded the iron. Wherry and Buchanan (1926) indicate aluminum as present in but small undetermined amounts in the 10–20 per cent ferric oxide found in the ash of North American material, which ash contained about 35 per cent SiO_2. Reiche's analysis, evidently overlooked by Wherry and Capen (1928), differs also from all the analyses collected by the latter in the low magnesium and sodium contents. Wherry and his co-workers concluded that dissolved matter in rain is the source of the ash in *Tillandsia*, and Reiche's analysis, if valid, may reflect a difference in composition in rainwater in his locality and in southeastern North America; contamination by dust, excluded by Wherry and Capen, may, however, be suspected in Reiche's material.

Gramineae

Hordeum vulgare L.

Robinson (1939) writes, "parts . . . such as barley hulls or barley grains, contain as much as 0.5 per cent" Al_2O_3. This is, however, out of harmony with the results of analyses made on experimental plants reported below and Levy records but 0.00067 per cent of the dry grain to be Al; many older investigators also found minute traces in wheat. Yoshii and Jimbo studied 31 species of the family with negative results.

Abietinae

The following data are available for pine and fir needles:

	Per cent Al in ash	*Per cent Al in dry plant*	
Pinus echinata	4.8	0.134	(Robinson, Steinkoenig, and Miller, 1917)
P. palustris	2.9	0.098	(Robinson, Steinkoenig, and Miller, 1917)
P. pumilio	0.127	0.00175	(Wittstein, 1862)
P. sylvestris	0.066	—	(Karmrodt, 1864)
P. sylvestris	0.2372	0.0065	(Levy, 1931)
Larix decidua	0.140	—	(Karmrodt, 1864)
Abies excelsa	0.755	—	(Karmrodt, 1864)

A capacity to accumulate aluminum appears to exist in a few species of *Pinus*, at least under certain soil conditions. Wherry (1932) found that the ash of *Pinus rigida* Miller contained 5.81 per cent Al when the tree grew on acid woodland soil, 2.20 per cent when from serpentine-barrens.

Wittstein's data for the wood (0.136 per cent–0.486 per cent Al in ash) of *P. sylvestris* have already been mentioned. In the bark of his three trees he found much more, namely 1.64 per cent to 5.36 per cent Al in the ash. In both bark and wood the amount present in the ash appears to increase with age, but this increase is less striking and less regular when the data are related to dry weight. It is not improbable that the bark analyzed contained contaminant material. Nemec and Maran (1939), in a paper known to the writer only by abstracts, have recorded pathological accumulation of aluminum accompanied by stunting in *Pinus sylvestris*. The condition was alleviated by treatment with various fertilizers containing phosphate and calcium. Larch and spruce trees responded less well to such fertilization.

In addition to these records, Kratzmann's microchemical studies suggest that *Ranunculus fluitans* Lam. (leaf) and *R. arvensis* L. (leaf), *Vitis vinifera* L. (bast), *Lathyrus niger* (L.) Bernh. (leaf), *Elaeagnus angustifolia* L., *Caucalis daucoides* L., *Sium latifolium* L., *Pulmonaria officinalis* L., and *Taraxacum officinale* Weber have a higher Al

content than most plants, but where quantitative results are available these records are not apparently confirmed. The last of them is apparently in accord with Sayre's (1897) report of 18.07 per cent Al_2O_3 in the ash of the root, but Sayre's material was obviously contaminated and the record of Berg of 0.0007 per cent in the living leaf and the recent report of Levy of 0.288 per cent Al in the ash of the dandelion root definitely indicate no abnormal accumulation. No other composite has ever been noted as an aluminum accumulator; Yoshii and Jimbo examined forty-nine species of the family with negative results. The records of Rotondi, L'Hôte, Ricciardi and Levy indicate no great accumulation in the grapevine. Yoshii and Jimbo studied no less than 18 species of *Ranunculaceae*, but found no qualitative indications of aluminum; it is improbable that they did not examine *Ranunculus* itself, so that Kratzmann's records, which are certainly less illuminating than those of Yoshii and Jimbo, hardly can be taken as indicating widespread accumulation in that genus. One old qualitative record, by Salm-Horstmar (1847), apparently confirming a statement of Berzelius, exists for *Helleborus niger* L., a member of the family, but its significance is uncertain. On the whole it is doubtful if Kratzmann's results are of great importance.

Similarly, using the same technique as Kratzmann, von Faber (1925, 1927) finds much aluminum in the leaves of *Myrica javanica* Bl. (*Myricaceae*), of *Albizzia montana* Bth. (*Mimosaceae*) and of *Rapanea avenis* (Bl.) Mez. (*Myrsinaceae*), and apparently rather less in *Ficus diversifolia* (Bl.) (*Moraceae*), when these plants grow in solfatara soils. It is impossible to ascertain if such qualitative recognition of the element should accord these species a place in the list of aluminum accumulators already given, but it is most interesting that in the Ericaceae and species of *Vaccinium* from these Javanese localities little accumulation occurs in the leaf. In all the solfatara plants much aluminum occurs in the root and von Faber (1927) obtained evidence of a metabolic rôle, as is indicated below.

Yoshii and Jimbo, using alizarin, find feeble qualitative indications of aluminum in *Potamogeton polygonifolius* Pourt. (*Potamogetonaceae*), *Aletris foliata* Franch (*Liliaceae*), *Stauntonia hexaphylla* Decne (*Lardizabalaceae*), feeble indications in *Skimmia japonica* (*Rutaceae*), *Ilex crenata* var. *typica* f. *genuina* Loes (*Aquifoliaceae*) and *Cornus canadensis* L. (*Cornaceae*), and more definite but slight indications in *Leucothoe grayana* Maxim. var. *Tschonoskii* Takeda (*Ericaceae*, 1.4 per cent Al in ash), *Osmanthus aquifolium* Sieb. var. *japonicus* Makino (*Oleaceae*) and in *Utricularia japonica* Makino (*Lentibulariaceae*).

Quantitative studies might well be made on all the plants in Kratzmann's list, and in that of Yoshii and Jimbo, but it is quite possible that nothing of interest would be found; all the Japanese plants just mentioned as giving slight indications would probably contain less than 2.5 per cent Al in the ash. Such qualitative investigations are in fact more apt to obscure than illumine the subject of plant biochemistry; but even with such a thought in mind it is difficult to know how to comment on Hallier's list of those plants that, in the herbarium, look as if they should be aluminum accumulators. They are supposed to be recognized by thick leathery leaves of a yellow-green color, presumably due to a yellow aluminum lake; this color, however, is by no means universal, even in the genus *Symplocos*, nor is it exhibited by *Aporosa sphaeridophora*, as Hallier observes, though this species is an aluminum plant.

The plants listed by Hallier are as follows: *Berberidaceae* (Yoshii and Jimbo give three unspecified negative records), *Kibara* spp. (*Monimiaceae*), *Capparis* spp. (*Capparidaceae*), *Erythroxylum paraense* and *E. cuneatum* var. *bancanum* (*Erythroxylaceae*), *Diapensia* (*Diapensiaceae*), *Prunus Laurocerasus*, *Eurya coneocarpa*, *E. coriacea*, *E. hellwigii*, *E. ternatana* (*Theaceae*), *Ochnaceae*, *Garcinia* spp. and *Calophyllum* spp. (*Guttiferae*), *Hypericum* spp. (*Hypericaceae*); *Xanthophyllum* and other *Polygalaceae; Qualea* spp. and *Vochysia tucanorum* (*Vochysiaceae*); *Alsodeia flavescens*, *A. Horneri*, *A. obtusa* (*Violaceae*); *Erythrospemum verticillatum* Lam.; *Ilex Aquifolium* L. (*Aquifoliaceae*); *Villaresia emarginata* R. and P. (*Icacinaceae*); *Griselinia* spp. and *Aucuba japonica* (*Cornaceae*) and *Buxaceae*. The most striking feature of the list is the inclusion of *Kibara*, *Diapensia*, and *Eurya*, genera that are indeed aluminum accumulators, as Yoshii and Jimbo, and Hutchinson and Wollack, found. But further study shows the criterion of color to be illusionary; Keilholz (1921) found but 0.04 mg. Al per kilo. in *Prunus Laurocerasus*, a result which, though doubtless too low, indicates that the species is not an accumulator. Hutchinson and Wollack examined species of several of the

other genera in Hallier's list, all, except the species of *Alsodeia*, showing most conspicuously the color and texture supposed to diagnose aluminum plants. In most cases the amount of material available was very small, and the figures indicate only the upper limit of the Al content:

Capparis ferruginea L.: $\leq$0.05 per cent Al in ash or 0.003 per cent in dry leaf
Calophyllum Whitfordi Merr.: $\leq$0.04 per cent Al in ash or 0.0008 per cent in dry leaf
Hypericum Kalmianum L.: $\leq$0.4 per cent Al in ash or 0.009 per cent in dry leaf
Ilex Aquifolia L.: $\leq$0.2 per cent Al in ash or 0.007 per cent in dry leaf
Alsodeia parvifolia* Watson: $\leq$0.6 per cent Al in ash or 0.05 per cent in dry leaf

* The correct name of the genus appears to be *Rinorea*, but to avoid the possibility of a new combination, this generic name has not been employed.

In view of these results, Hallier's criterion appears to be valueless, though since three of nine genera in Hallier's list that have been analyzed have proved to be aluminum plants, it is possible that a low statistical correlation between color and aluminum content does exist. Hallier also suggests that *Agation violare* and *Strasburgera*, on account of sphaerocrystalline bodies found in the epidermis, may be aluminum plants.

Apart from analytical study, the only certain indication of the presence of large amounts of aluminum is the traditional use of a plant as a mordant. Many of the notable cases (i.e. *Melastomaceae*, *Aporosa*, *Baccaurea*, *Symplocaceae* and *Lycopodium*) have been discovered in this way. It is remarkable that plant mordants have been employed primarily in S. E. Asia; it is possible that an equally large number of aluminum accumulators occur in other tropical floras, but the technological processes not being developed, they have escaped detection. Hooker (1813, ii, p. 322) quotes Linnaeus to the effect that the leaves of *Arctostaphylos Uva-ursi* are used in Lapland and Sweden for tanning and dyeing (Linnaeus' *Lachesis Lapponica* V. 1, p. 250). Reference to the *Flora Lapponica* (Linnaeus, 1737) indicates only a reference to tanning, and no statement, as is implied by Hooker, that the leaves save a "great deal of alum."

When a fuller understanding of the distribution of aluminum accumulators is achieved, it is possible, as Hallier believed, that a high concentration of the element may be found to characterize not merely certain species, genera, and families, but also rather loosely defined groups of allied families. It is, however, clear that even within a family, such as the *Theaceae*, not all species show the condition, which may merely be an inconstant symptom of some more fundamental physiological character of the group. At present, however, for want of adequate data, all such speculations are idle dreams.

(*To be continued*)

MATING TYPES IN THE CILIATE PROTOZOA

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INTRODUCTION

THE occurrence of mating types in the ciliate protozoa was first reported by Sonneborn in 1937 for *Paramecium aurelia*. This discovery not only opened up many opportunities for genetic research with the ciliates but revealed a phenomenon which merits study for its own intrinsic interest.

In brief, Sonneborn's discovery was this. When he mixed together animals of certain clones an immediate clumping of the animals into large masses occurred. Out of these masses were formed many pairs of animals undergoing the sexual process, conjugation. However, when he mixed other clones no clumping or conjugation occurred. He soon found that the clones he was studying could be divided into two classes. Only when he mixed clones of different classes did clumping and conjugation occur. These classes were at first designated sexes but have since been called mating types.

In reviewing the work done on mating types, we shall deal with several different problems. What systems of mating types are found when many clones of diverse origin are studied? What implications do these systems have for evolution within these organisms? What is the relation of mating types to sex and other phenomena in higher organisms? How are the mating types inherited? What are the conditions under which diversity of mating type brings about conjugation? What is the nature of the diversity in animals of different mating types that leads to conjugation?

Systems of mating types

Study of many clones from many sources in nature led Sonneborn ('38a) to the following scheme of mating types within the species of *Paramecium aurelia* (Table 1). First of all he found that the species can be divided into three groups or varieties. When clones of different varieties are mixed, no conjugation occurs. Within each variety he found two mating types. Animals of the same variety but of different mating types are the only ones which conjugate when they are mixed. The mating types of the three varieties were designated I and II, III and IV, V and VI. No morphological differences were found between the three varieties though physiological differences of several sorts were found.

Jennings began work on *Paramecium bursaria* shortly after Sonneborn's discovery. He ('38, '39 b, and c) found a somewhat more complicated system of mating types in this species (Table 1). As in *P. aurelia* three non-intermating varieties were found. However, there were not just two mating types in each variety but four in two of them and eight in the other. Clumping and conjugation occur when clones of any two mating types of the same variety are mixed but does not occur when clones of the same mating type are mixed. The sixteen mating types in this species have been designated with the capital letters A to Q.

Gilman ('39, '41) has reported a situation in *P. caudatum* much like that in *P. aurelia*. Only two mating types were found in any one non-intermating variety. However, five and not three varieties were reported.

Mating types have been reported for several other species of *Paramecium*. Giese and Arkoosh ('39) and Giese ('39) report them for *P. multimicronucleatum*; Sonneborn ('38) for *P. trichium* and *P. calkinsi*; and Boell and Woodruff ('41) for *P. calkinsi*. Most of these investigations were not carried out on an extensive scale to ascertain the number of types. However, Giese ('41) has recently reported a set of four mating types in *P. multimicronucleatum*.

Mating types are apparently a universal phenomenon in *Paramecium*. Are they found in other genera? Jennings ('39a) points out that some results of Maupas (1888) can be interpreted as strong evidence for mating types in several genera.

However, definite evidence is available for only one other genus, *Euplotes*. Kimball ('39c) reports the occurrence of six mating types in one variety of *Euplotes patella* (Table 1). At least one and perhaps two other non-intermating varieties of this species were present in the stocks studied, and mating types occur in these varieties also. The investigation of mating types has been made in detail only with the first mentioned variety. In addition to these non-intermating but morphologically identical varieties, two other groups of stocks were found which are slightly different morphologically from *E. patella*. Mating types were found in both of these groups. No conjugation occurs when the mating types of either of these groups are mixed with those of the other group or with the mating types of *E. patella*. These groups must be considered as separate species which are very similar to *E. patella*.

TABLE 1

Mating types and varieties in three different species of ciliates

The plus sign indicates that conjugation occurs; the minus sign that it does not

Paramecium aurelia

VARIETY		1		2		3	
	Type	I	II	III	IV	V	VI
1	I	−	+	−	−	−	−
	II	+	−	−	−	−	−
2	III	−	−	−	+	−	−
	IV	−	−	+	−	−	−
3	V	−	−	−	−	−	+
	VI	−	−	−	−	+	−

Euplotes patella

TYPE	I	II	III	IV	V	VI
I	−	+	+	+	+	+
II	+	−	+	+	+	+
III	+	+	−	+	+	+
IV	+	+	+	−	+	+
V	+	+	+	+	−	+
VI	+	+	+	+	+	−

Paramecium bursaria

VARIETY		I				II								III			
	Type	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q
I	A	−	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−
	B	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	−
	C	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−
	D	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−
II	E	−	−	−	−	−	+	+	+	+	+	+	+	−	−	−	−
	F	−	−	−	−	+	−	+	+	+	+	+	+	−	−	−	−
	G	−	−	−	−	+	+	−	+	+	+	+	+	−	−	−	−
	H	−	−	−	−	+	+	+	−	+	+	+	+	−	−	−	−
	J	−	−	−	−	+	+	+	+	−	+	+	+	−	−	−	−
	K	−	−	−	−	+	+	+	+	+	−	+	+	−	−	−	−
	L	−	−	−	−	+	+	+	+	+	+	−	+	−	−	−	−
	M	−	−	−	−	+	+	+	+	+	+	+	−	−	−	−	−
III	N	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+
	O	−	−	−	−	−	−	−	−	−	−	−	−	+	−	+	+
	P	−	−	−	−	−	−	−	−	−	−	−	−	+	+	−	+
	Q	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	−

It may be concluded that the phenomenon of mating types is widespread if not universal among the ciliates.

Evolutionary implications

The evolutionary implications of the mating type systems are of some interest. The non-intermating varieties of a species do not differ from one another morphologically as far as has

been detected. They differ primarily in their inability to conjugate with one another and also in certain physiological characters such as the temperature and light conditions required for conjugation and the production of lethal substances. Sonneborn ('39b) points out that the absence of morphological differences makes it highly inconvenient to consider them separate species despite the fact that some investigators would consider the sexual isolation a sufficient species distinction.

The genus *Paramecium* is made up of a number of species, and these can be grouped into the caudatum-like and the bursaria-like forms (Wenrich, '28). These groups are based primarily on the body form and when other characters are considered quite different groupings would result. On the other hand, in *Euplotes*, there is a group of species very closely resembling *E. patella* and differing considerably from the other species in the genus (Pierson, unpubl.). As mentioned above, none of these species will conjugate with each other although more than one mating type has been found for each. In one of these species, *E. patella*, two morphologically identical non-intermating varieties have been found.

These facts suggest the conclusion that in ciliates one of the first steps in speciation is sexual isolation. How this arises can only be speculated upon at present. Presumably some sort of geographical or ecological isolation is the first step. Sexual isolation would then be expected to be followed by the accumulation of physiological and morphological differences. Only when morphological differences have appeared is it convenient to consider that a new species has been formed. In *Paramecium* we see primarily sexual isolation with the accumulation of some physiological differences. In *Euplotes*, we find sexual isolation and also evidence of relatively recently established morphological differences.

If sexual isolation arises in this manner we should not be surprised to find that the mating types of different varieties of a species are homologous. Evidence that this is so was obtained by Sonneborn ('39b) in *P. aurelia*. He found that when animals of type II of variety 1 are mixed with animals of type V of variety 3, a very weak mating reaction occurs. Pairs form for a few minutes but break apart so that conjugation is never completed. This suggests that type II is homologous with type VI and type I with type V. It also suggests that sexual isolation does not arise in one step. Varieties 1 and 3 though completely isolated still retain a certain amount of similarity. This is further attested by the fact that variety 2 which never gives a weak reaction with the other varieties is more unlike varieties 1 and 3 in physiological characters than these two are unlike each other. If sexual isolation arose in one step, we would not expect to find differences in the ability to undergo the mating reaction as shown by the varieties of *P. aurelia*.

Nuclear changes in ciliates

For the rest of the discussion, a knowledge of the nuclear changes that occur in ciliates is necessary. The ciliates are peculiar in possessing two types of nuclei, the large macronucleus and the small micronucleus. Reproduction is accomplished by fission during which the macronucleus divides amitotically and the micronucleus divides mitotically.

At intervals fission is interrupted by other processes. The most widespread of these is conjugation. In this process, two animals pair side by side. The micronuclei in each animal undergo two divisions which are probably meiotic. This is followed by a third, probably mitotic division of one or more of the products of the first two divisions. Two of the products of the third division become the pronuclei. There is evidence, both cytological and genetical, that the two pronuclei in an animal come from the division of only one of the products of the second division. One of the pronuclei from each animal passes over into the other animal and fuses with the pronucleus remaining in that animal to form a synkaryon. Conjugation is thus a process of reciprocal fertilization, each animal fertilizing the other.

While these events are occurring the old macronucleus degenerates. Generally it fragments into a number of pieces which are resorbed over the course of one or several fissions after conjugation. A new macronucleus is formed from some of the products of the mitotic division of the synkaryon. In *P. aurelia* and *P. bursaria* the synkaryon divides twice, and two of the products enlarge to form the anlagen of the new macronucleus. One or both of the other products become micronuclei. The two anlagen are segregated to the two products of the first cell division following conjugation and then assume the typical size and structure of the macronucleus. The

micronuclei are not segregated but divide mitotically at the first division. In *Euplotes* the synkaryon divides twice but only one of the products develops into a macronuclear anlage and one into the micronucleus. The other two are resorbed.

Other types of nuclear reorganization besides conjugation occur. These all involve one instead of two animals. The first of these to be adequately studied cytologically was endomixis reported by Woodruff and Erdmann (1914) in *P. aurelia*. In this process the old macronucleus is fragmented and resorbed. It is replaced by products of the mitotic division of the micronucleus. This process has not been found by Sonneborn in the stocks of *P. aurelia* which he has investigated for mating types. Instead another process frequently occurs. This is autogamy, first described cytologically by Diller ('36) and later shown to occur by Sonneborn ('39b) using genetic methods. This process is essentially the same as conjugation save that it occurs in a single animal. Two pronuclei are formed as in conjugation, and these fuse to form a synkaryon. This synkaryon divides twice, and two macronuclear anlagen and two micronuclei are formed as in conjugation. The macronuclear anlagen are segregated to separate animals at the first cell division following autogamy and enlarge to form new macronuclei which replace the previously fragmented old macronucleus.

Recently Sonneborn ('42a) has reported yet another process of nuclear reorganization within a single individual in *P. aurelia*. In this process the macronucleus fragments but the micronuclei undergo no change. Indeed in many cases, though not all, the animals undergoing this reorganization are amicronucleate. The fragments of the macronucleus are segregated to different individuals at succeeding fissions until individuals arise with only one fragment. This fragment enlarges into a macronucleus of normal size and structure. Animals in which such macronuclear regeneration has occurred are capable of continued growth and division though they are not fully normal. Apparently a small fragment of the macronucleus is capable of carrying out nearly all of the functions of the whole macronucleus.

In *P. bursaria* endomixis has been described by Erdmann ('27). Jennings ('41d) has not found it cytologically, though some of his data indicates that it may occur occasionally. No other process of nuclear reorganization within a single animal has been reported in this species.

In *Euplotes patella*, Kimball ('42) reports that he has not been able to find any sign of a nuclear reorganization process within a single animal.

Thus in *P. aurelia* several nuclear reorganization processes occur within the single individual. In the other species in which the mating types have been extensively studied, little if any such reorganization occurs.

Relation of mating types to sexuality and other phenomena

With a knowledge of the nuclear changes in conjugation, it is possible to consider the question of the relation of mating types to sexual differentiation in other organisms. This question has been discussed in detail by Sonneborn ('39a, b, '41a) and by Jennings ('39c). Jennings inclines to the view that the phenomenon of mating types is most similar to the phenomenon of self-sterility in plants and some animals. Sonneborn points out certain objections to this view. Both state that the major difficulty in considering mating types as comparable to sexes is that the two individuals brought together in conjugation mutually fertilize one another. Sonneborn appears to incline toward the view that mating types are most closely comparable with sexual differentiation. However, Sonneborn emphasizes that the only fruitful basis of inquiry is a knowledge of the nature of the processes involved. The reviewer agrees heartily with this. The problem is not to attempt to assign the phenomenon of mating types to a category of phenomena set up for very different organisms, but rather to understand the physiological processes involved. The union of individuals belonging to diverse mating types is one of a group of phenomena which involve the union or sticking together of cells. Until the nature of the physiological mechanisms involved in all such cases are more adequately understood, any comparisons are likely to degenerate into fruitless arguments over definitions. It is fortunate that the term mating type which does not imply similarity with other phenomena has been adopted in this work.

Inheritance of mating types

The question which has from the first occupied the center of attention of the investigators is the inheritance of mating types. At present, information is available on this subject for the species *P. aurelia*, *P. bursaria*, *E. patella*, and to a limited extent *P. caudatum* and *P. multimicronucleatum*.

We will be concerned with inheritance during or after the following processes: fission (vegetative reproduction), macronuclear regeneration, autogamy, and conjugation. We will consider fission first. It involves a cell division during which the micronucleus divides mitotically and the macronucleus, amitotically. There is no reason to believe that genic changes other than mutations would occur during this process. Sonneborn ('37, '39b) for *P. aurelia*, Jennings ('39b and c) for *P. bursaria*, Giese ('39) for *P. multimicronucleatum*, Gilman ('41) for *P. caudatum* and Kimball ('39c) for *E. patella*, have shown that in general mating type is inherited unchanged during vegetative reproduction. However, a number of apparent exceptions have been found. In considering these, we will disregard for the moment the divisions immediately following conjugation and autogamy since these present special problems.

In *P. aurelia*, Kimball ('39b) found a few (less than 3 per cent) exceptional clones in which the mating type was not constant but changed from time to time. As a result, cultures of such clones usually contained a few conjugant pairs. The change of type in such clones was shown to occur in both directions, from type I to type II and from type II to type I; and it was shown to be reversible. However the mating type of each individual animal was not determined completely independently of any other animal, for when an animal of known mating type was isolated its descendants were mainly of the same type as itself. Thus the mating type was inherited in these clones over a period of several divisions and then changed. From some of the "unstable" clones of this sort, lines were isolated in which no further change of type occurred. It is an interesting though unexplained fact that these "stable" lines were always of the same type as the clone from which the "unstable" clone was derived by autogamy. As Sonneborn ('42a) has pointed out, this case is an example of intraclonal diversity which in the "stable" lines remains constantly inherited once it has arisen. Other cases of intraclonal diversity inherited in subsequent fissions have been reported for the ciliates. Sonneborn ('42a) discusses these cases and their interpretation. This whole matter is in need of further detailed analysis. At present such cases do not fit very satisfactorily with what is known of inheritance in higher forms.

In other species, conjugant pairs occur in cultures descended from a single animal. In some of these cases it seems probable that change of mating type during fission has occurred. In other cases the interpretation is not so clear.

Jennings ('41d) occasionally finds conjugation in cultures of *P. bursaria*. He is inclined to believe that this is the result of a change of mating type during endomixis. For this reason this case will be considered later. However, the evidence that endomixis or some such process is involved is not complete, so that change of type during vegetative reproduction is a possibility in this case.

In *P. caudatum*, Gilman ('41) has found a great deal of conjugation in cultures derived from single animals. In some cases nearly 100 per cent of the animals in a culture conjugated. Some clones were found in which none of this conjugation occurred. Gilman did not demonstrate that this conjugation resulted from a change of type though it seems probable that it did. If change of type did occur, autogamy or endomixis cannot be completely ruled out as a cause of the change, but several experiments in which a close watch for these processes was kept make such an interpretation unlikely. It seems more probable that change of mating type during vegetative reproduction is involved and that it occurs in most clones of *P. caudatum*.

Giese and Arkoosh ('39) and Giese ('39) have reported conjugation among the descendants of single individuals of *P. multimicronucleatum*. The causative factors in this case are not known though again change of mating type during vegetative reproduction is not improbable.

Conjugation among the vegetative descendants of a single animal in the absence of autogamy or endomixis has been reported for *Uroleptus mobilis* by Calkins ('19), for *Spathidium spathula* by Woodruff and Spencer ('24), for *Euplotes patella* by Cohen ('34), and for *Blepharisma undulans* by Woodruff ('35). In none of these cases were mating types shown to exist. However, it seems not unlikely that the conjugation was the result of a change of type during vegetative reproduction.

The situation in *E. patella* has been more recently investigated by Kimball ('42). In this species it has been shown that animal-free culture fluid from cultures of one mating type will induce conjugation in animals of a different type. It is possible that the fluid acts by inducing a change in mating type in some of the animals. It seems

more probable, however, that it acts by inducing conjugation among animals of the same type. Kimball ('39c, '42) finds conjugation among animals descended from a single animal rather frequently in this species. No endomixis or autogamy has been found. It is quite possible that change of mating type during vegetative reproduction is responsible for this conjugation. However, in view of the suspicion that conjugation may occur between animals of the same mating type, a change of mating type may not be necessary to explain this conjugation.

In concluding the section on inheritance during vegetative reproduction, it may be said that the mating type is ordinarily inherited unchanged. In *P. aurelia*, change of mating type during fission has been demonstrated. In several other forms there is reason to suspect that it occurs, but different explanations cannot be excluded.

The nature of the change of mating type during vegetative reproduction is an interesting problem. It may be suggested that it is similar to the changes which lead to differentiation of cells during embryonic development in multicellular forms. As in this latter case, there is no good reason to postulate genic changes though mutation cannot be ruled out as a factor.

We will turn now to the inheritance of mating types following various nuclear reorganization processes and consider first of all macronuclear regeneration as reported for *P. aurelia* by Sonneborn ('42a). In this process the micronuclei undergo no change. The macronucleus fragments into a number of pieces, and each fragment finally becomes segregated to a single animal after a number of fissions. There it develops into a normal appearing macronucleus. The mating type is unchanged by this process as might be expected since no rearrangement of genic material has occurred. The case indicates that the macronucleus is a compound structure, possibly highly polyploid, since each fragment of the macronucleus can give rise to a more or less normally functioning nucleus.

The inheritance of mating type at conjugation and at autogamy or endomixis will be considered together since they have close connections with one another. In *P. aurelia*, the two processes have practically identical results for mating type inheritance. Sonneborn ('37) and Kimball ('37) found that autogamy in certain stocks of variety 1 of *P. aurelia* produced clones of both the mating types of the variety. Later Sonneborn ('39b) found stocks in this variety in which no change of mating type occurred at autogamy. All the clones of such stocks were type I. When such one-type stocks were crossed to the more common two-type stocks, the difference between them was found to depend upon a factor showing ordinary Mendelian inheritance. The one-type condition was recessive to the two-type. This factor must be localized withon one chromosome because of the method of its inheritance. We cannot say that it is a single gene, though this seems very probable from what is known about other organisms. In the rest of the paper it will be called a gene for the sake of simplicity.

Each clone of a two-type stock is of a particular mating type. What determines this type? The answer to this question is not finally established but considerable information and a reasonable hypothesis are available. Sonneborn ('37, '39b) showed that the mating type is determined by the macronucleus. This was done in the following way. The two products of the first division of each exconjugant were isolated and allowed to give rise to clones. Thus four clones were obtained from each pair. The two clones from an exconjugant were sometimes alike in mating type but were frequently different. It was shown that the mating types are distributed at random to the four clones from a pair since these four clones from one exconjugant were alike no more frequently than would be expected by chance alone. This also leads to the conclusion that the type of the conjugant at the time of conjugation has no effect upon the type of its descendants.

Thus the mating type of each of the two products of the first division of an exconjugant is determined independently. However, this is not so of the products of later divisions than the first. What is the basis of this difference between the first and all subsequent divisions? The one cytological phenomenon peculiar to the first division is the segregation of the two new macronuclei to different sister individuals. This fact leads to the conclusion that it is the macronucleus which determines the mating type and that the type which a macronucleus is to determine is fixed at some early stage in its development. This hypothesis was confirmed by Sonneborn ('39b). He found a stock of variety 1 in which the mating type frequently segregated at the second division following conjugation. Correlated with this was the fact that

more than the two new macronuclei are frequently formed in this stock. Since the segregation of the macronuclei in these cases is not completed till the second or later divisions, segregation of mating types would be expected to occur sometimes at the second division.

These same general relations were also found at autogamy by Sonneborn ('37, '39b) and Kimball ('37). This is not surprising since autogamy and conjugation are alike in nuclear processes save that autogamy occurs in one animal only. In both processes pronuclei are formed and fuse to form a synkaryon, and two macronuclei are formed from this synkaryon and are segregated at the first division following the process.

What is the nature of the process which fixes the macronucleus so that it will determine a specific mating type and when does the fixation occur? Answers to these questions come partially from a study of the frequency of the two mating types among exconjugant and exautogamous clones. Kimball ('37) and Sonneborn ('39b) found that the ratio of the two types varied greatly in different experiments. In variety 1 ratios of type II to type I ranging from 0.5 to 3.4 were found. In variety 3 ratios of type VI to type V of 0.9 to 3.5 were found. Sonneborn ('39b) found that the ratio was markedly affected by the temperature at which the exconjugants were kept. A temperature of 10°–19° C. in variety 1 or 10°–14° C. in variety 3 resulted in ratios of approximately 1.0. Temperatures higher than this resulted in ratios up to about 2.0 at 30° C. Further studies showed that the temperature during the reorganization of the exconjugant was the determining factor. This is the period during which the two new macronuclei are forming within a single animal. Therefore the mating type to be determined by each of the macronuclei is fixed independently while they are still together in the same cytoplasm.

There are several ways in which such a result might be conceived to come about. The divisions giving rise to the two new macronuclei might involve some sort of genic segregation. The fixing of the type might involve some sort of inheritance of an environmental effect produced on the macronucleus, similar perhaps to some of the effects postulated by Jollos ('21) in his *Dauermodification* hypothesis. Finally, a mutable gene for mating type might be involved, mutating with a very high frequency at the stage of macronucleus formation only.

The first possibility can be excluded for two reasons. In the first place, the cytological study of the divisions leading to the formation of the macronuclei from the synkaryon indicates that they are normal mitoses. In the second place, Sonneborn ('42a) showed that following five successive occurrences of autogamy in clones of type I both mating types were still produced and the same thing was true following five successive occurrences of autogamy in clones of type II. Sonneborn ('39b) had already shown that one autogamy results in complete homozygosity for the one-type, two-type gene and because of the nature of the nuclear processes would presumably do the same thing for any other genes. Five successive occurrences of autogamy should be more than sufficient to insure that all genes are homozygous, and so segregation could not explain the occurrence of both types among the progeny of the last autogamy.

Non-genic determination of the sort suggested in the second hypothesis was favored by Sonneborn ('42a) in a paper delivered orally in 1940. However, no proof for such an hypothesis can be given, and it would involve entirely new genetic principles.

More recently Sonneborn ('42b) has accepted the last hypothesis as most probable. He assumes that the recessive allele of the gene determining the difference between one-type and two-type stocks is actually a stable gene for type I. The "dominant allele" is an unstable allele for type I which mutates with a very high frequency (38–87 per cent) to an allele for type II. This mutation occurs only during the stage of macronuclear formation and is temperature sensitive. This hypothesis fits the facts very well, but it involves some rather remarkable assumptions. Nevertheless, mutable genes are known for multicellular forms and some of these mutate with quite a high rate at particular stages in development. This hypothesis is the best available so far, but it must be accepted with some caution.

One other aspect of mating type inheritance in *P. aurelia* is of interest. Kimball ('39a) showed that, after a change of mating type from type II to type I as a result of autogamy, not all the animals changed type immediately. Following the first few divisions of the product of the first division after autogamy there were still some type II individuals. If these type II animals are isolated, the cultures from them are all type I. Thus there

is a lag in the change from type II to type I. No such lag was found for the reverse change. Sonneborn ('39b) confirmed these observations for other stocks in variety 1 and found the same thing in variety 3. In the latter, the lag occurs only in the change from type VI to type V. I should like to point out that these facts can also be explained by Sonneborn's mutable gene hypothesis. The type II allele produced by mutation of the mutable type I allele would have to be dominant. Otherwise, since the nucleus from which the macronucleus comes is diploid, it would have to be assumed that both type I alleles mutate at once. Following autogamy or conjugation fragments of the old macronucleus remain in the cytoplasm for several divisions. If these fragments contained the dominant type II allele they might continue to exert an effect in the presence of a type I determining macronucleus. However, if these fragments contained only the type I allele, their effect would be masked if the new macronucleus were type II. The fact that the mutable gene hypothesis can explain the otherwise unexplained difference in the reciprocal changes lends it considerable support.

Turning now to the inheritance of mating types in *P. bursaria*, a much less clear situation is found. Jennings ('41d, '42) has recently reported detailed studies of this inheritance for variety I with its four mating types A, B, C, and D. Less complete studies have been made with variety II with eight mating types. Variety III has not been studied. The situation in variety II seems to be the same as that in variety I.

Two major types of inheritance must be considered. First of all there is the phenomenon Jennings calls self-differentiation which he believes involves a change of type at endomixis or autogamy. Secondly, there is inheritance following conjugation. Self-differentiation will be considered first. Jennings ('41d) reports that the mating type remains unchanged over many cell divisions but occasionally pairs appear in cultures derived from a single animal. He has shown that these pairs consist of animals of different mating types. This appearance of more than one mating type among the descendants of a single animal Jennings calls self-differentiation. He is inclined to consider it a result of endomixis which Erdmann ('27) reported occurred rarely and sporadically in this species. However, no direct evidence that endomixis occurs has been obtained by Jennings, so that the possibility that self-differentiation is due to change of mating type during vegetative reproduction cannot be excluded.

The most important fact about self-differentiation is that whenever it occurs just two mating types result, the type present prior to self-differentiation and a derived type. For any one clone, these two types are characteristic. Successive self-differentiations always give the same pair of types. All six possible combinations of mating types have been found in different clones (AB, AC, AD, BC, Bd, CD). Different clones originally of the same mating type may produce different derived types. Thus there is little evidence of any systematic relation between the mating types in self-differentiation save that any particular clone is capable of producing only a particular pair of types. No explanation can be offered for these facts though they may be of considerable importance for the solution of the problem of mating type determination in this species.

The study of inheritance of mating types following conjugation has also yielded results of interest (Jennings, '41d, '42). The first result is that the four clones produced by an exconjugant pair (derived from the two products of the first division of each conjugant) are generally alike in mating type. A few pairs were found in which the two conjugants gave rise to progeny of different mating types and a few others in which the two products of the first division produced clones of different types. The fact that the two members of a pair generally give rise to clones of like type can be taken as strong, though not final evidence, that mating type determination is genic. This is so for the following reason. The two pronuclei of an exconjugant are probably derived by mitotic division from a single reduced nucleus and so should be of the same genic constitution. The synkarya formed in the two conjugants should therefore be genically alike since each comes from the union of a pronucleus from one conjugant with one from the other.

The next question to be considered is what effect the mating types of the conjugants have on the types of their descendants. In variety I all possible matings have been made between the four types. In general about half the pairs produce clones of one of the parental types, and half of the other type. In most cases a few clones are produced which are of types other than the parental ones. In a very few cases, Jennings ('42) found

one of these non-parental types to be more frequent than one of the parental types. Of the six possible combinations of mating types, all save one (B x C) has at one time or another produced clones of each of the four mating types. The combination B x C has produced three of the four types and might well produce the fourth in future trials.

One type of conjugation, that between the two types produced by self-differentiation, has not been considered yet. It might be thought that since only two types are produced by self-differentiation only these same two types would be produced by conjugation between them. However, this is not the case. All four types have been produced by conjugation following self-differentiation in variety I (Jennings, '41d).

In one other species of ciliate, *Euplotes patella*, the inheritance of mating types at conjugation has been studied. Kimball ('42) has presented evidence from breeding experiments that the six mating types in the one variety studied are determined by the six possible combinations of a series of three allelic genes. There is no dominance between these alleles, the heterozygous combinations determining different mating types than the homozygous ones.

Evidence concerning the way in which these alleles act comes from other experiments. Kimball ('39c, '41) has shown that animal-free fluid obtained from a culture of one mating type will induce conjugation among animals of certain other mating types. When all possible combinations of fluid and animals are made, a system of reactions is obtained which throws considerable light on the action of the mating type alleles (Table 2). Fluid from any of the heterozygous types induces conjugation among animals of any type other than its own. Fluid from any homozygous type induces conjugation only among animals of those types which do not have the same allele as the type from which the fluid came. These facts are most simply explained if it be assumed that each of the mating type alleles is responsible for the production by the animal of a specific conjugation-inducing substance. An animal is induced to conjugate only by those substances which it does not produce.

On this scheme the two alleles in a heterozygote act independently of one another. Each is responsible for the production by the animal of a specific substance and an immunity, as it were, to the action of that substance. Thus heterozygous animals are induced to conjugate only by fluid

TABLE 2

The results of mixing animals of various mating types with animal-free fluid from various mating types in Euplotes patella

The plus sign indicates that conjugation occurs; the minus sign that it ordinarily does not. The genotypes of the various mating types are given

TYPE ANIMALS		I	II	III	IV	V	VI
Fluid	Genotype	mt^1mt^2	mt^1mt^3	mt^2mt^3	mt^1mt^1	mt^2mt^2	mt^3mt^3
I	mt^1mt^2	−	+	+	+	+	+
II	mt^1mt^3	+	−	+	+	+	+
III	mt^2mt^3	+	−	−	+	−	+
IV	mt^1mt^1	−	−	+	−	+	+
V	mt^2mt^2	+	+	+	+	−	+
VI	mt^3mt^3	−	+	+	+	−	−

Jennings has not been able to suggest a genetic mechanism that will satisfactorily explain these various results. The only thing that seems fairly clearly established is that genic factors are involved. It seems to the reviewer probable that despite the large amount of work that has been done, the number of matings made to date is not sufficiently large to show all the relations in what is probably a very complex case. This seems particularly likely in view of Chen's ('40) demonstration of polyploidy in this species. If all or many of the stocks studied were polyploids rather complicated results might appear. In addition the fact that a number of clones have shown a double potentiality, producing a specific pair of mating types at self-differentiation, seems very important. It is possible, in the reviewer's opinion, that not the mating type of the clone but what it produces at self-differentiation should be the character followed in genetic studies.

from animals which have an allele not possessed by the heterozygotes.

The independent action of the alleles is confirmed by the work of Powers ('42). Kimball ('41) had obtained double animals of *E. patella* which contained two micronuclei and two macronuclei in a common cytoplasm. He had shown that the two halves of such a double sometimes contained nuclei determining different mating types. Powers made use of this material to obtain animals with two nuclei, each homozygous for a different allele. The mating type of these doubles was found to be the same as that of single animals with one nucleus heterozygous for the same two alleles. Thus it makes no difference whether two alleles are in the same or different nuclei. It is interesting to note that the heterozygous type is dependent upon the presence of both halves of the double. Single animals can be obtained from both halves; and when this is done the clones from the two singles are of different homozygous types. There is no apparent carry-over of the effects of a nucleus once it has been lost.

The determination of mating types in the different species seems very different. However, the difference between the genetic mechanism in *P. aurelia* and in *E. patella* is not quite so great if we accept Sonneborn's mutable gene hypothesis. There is a similarity in that the mating types in both species are determined by a series of allelic genes. There is nothing in *E. patella* that corresponds to the mutable allele or the dominant type II allele of *P. aurelia*. Likewise there is nothing in *P. aurelia* that corresponds to the heterozygous mating types of *E. patella*. Sonneborn's ('42a) other hypothesis of mating type determination in *P. aurelia* has practically nothing in common with the hypothesis for *E. patella*. Jennings' ('42) results with *P. bursaria* cannot be explained as yet but they certainly do not seem to resemble the results for the other two species. It is remarkable that such a wide-spread phenomenon as mating types should depend on such very different genetic mechanisms even in different species of the same genus.

The mating reaction

In *Paramecium*, the most striking result of bringing together animals of diverse mating types is an immediate agglutinative mating reaction. The animals stick together in large clumps of sometimes a hundred or more individuals. After some time these clumps break up into conjugant pairs. This reaction was first reported by Sonneborn ('37) for *P. aurelia*. It has been studied in more detail by Jennings ('39c) for *P. bursaria*. Photographs of the reactions are given by Jennings ('39a). It has been found by Giese and Arkoosh ('39) for *P. multimicronucleatum*, by Boell and Woodruff ('41) for *P. calkinsi*, and by Gilman ('41) for *P. caudatum*. Kimball ('39c) has never found it in *E. patella*. In this last species, when animals of different mating type are mixed, nothing happens for several hours. Then the animals come together in pairs, never in large clumps, and conjugation results. Thus the mating reaction seems to be general for the genus *Paramecium*. Whether it occurs in other genera has not yet been ascertained.

In *Paramecium*, the investigations of Sonneborn ('37, '39b) and of Jennings ('38, '39c) have shown that the pairs which form as a result of the mating reaction are always between animals of different types. Even in the large clumps union is always or almost always between animals of different types. However, Kimball ('39c, '41) has shown that in *E. patella* conjugation is not always between animals from clones of different type. When two clones are mixed, pairs consisting of two animals of the same clone are frequently formed as well as pairs between animals of different clones. This is undoubtedly the result of the fact that fluid from animals of one type will induce conjugation among animals of another type.

Jennings' ('39c) investigation of the mating reaction in *P. bursaria* shows that the animals come together by chance and not by any attraction for one another. When two animals of different mating types hit one another they stick together, and as more animals strike this group they likewise stick until a large clump of animals is formed. The animals show no attempt to coordinate their movements. Each apparently "tries" to move in its normal way. Since the animals may stick together in any position and by any parts of their surface, this leads to the group floundering about in an irregular way through the fluid.

According to Jennings ('39c) the animals that stick together have a space between them of the length of a cilium. This would seem to indicate that the cilia are involved in the sticking. However, Tartar and Chen ('41) have noticed that there is frequently an indentation of the body in the region of union. Thus there seems to be a local

reaction of the body to the union. The process is not quite as simple as a mere sticking together of cilia.

So far only the actual sticking together of the animals has been discussed. Since the animals may stick in any position and more than one individual may be stuck to another, the animals must move about on one another until they get into the proper position for conjugation. Then, presumably, the pair breaks away from the rest of the clump. There are thus two parts to the mating reaction, sticking together of the animals and moving into the proper position for conjugation.

These two parts of the reaction can be shown to be separate on other grounds than simple observation. Under certain conditions, the mating reaction may not be followed by conjugation. Sonneborn ('38a) showed this for variety 1 of *P. aurelia* and Gilman ('41) for *P. caudatum.*

Effects of environment and other factors on conjugation and the mating reaction

The presence of animals of different mating types or of fluid from one mating type and animals of another is not the only prerequisite for conjugation. Maupas (1889), Jennings ('10), and Giese ('35) have all stressed the role of food supply. The most favorable time for conjugation according to this work seems to be shortly after the depletion of a considerable supply of food. This same condition seems necessary when animals of different mating types are mixed. Sonneborn ('37), Jennings ('38, '39c), Kimball ('39c), and Gilman ('41) have reported that very well fed animals fail to conjugate. The failure of conjugation between very well fed animals is thus a very wide spread, perhaps universal occurrence. Extreme starvation also inhibits conjugation.

Other work on the conjugation inducing effects of salts, waste products, and particular species of bacteria is reviewed by Giese ('35). Most of these effects have been reported but a single time.

In more recent work temperature has been found to be a very important controlling factor for the mating reaction. Sonneborn ('38b, '39b, '41b), Giese ('39) and Gilman ('39, '41) have reported that conjugation only occurs within a certain range of temperature. One of the interesting results of this study is that different varieties have different temperature requirements. The most extensive investigation is by Sonneborn on *P. aurelia.* In variety 1 of this species, the mating reaction occurs when the two types are mixed at any temperature in the range of 10° to 38° C. Above and below this range it does not occur. In the range from 10° to 15° C. the mating reaction occurs but is very seldom followed by conjugation. In variety 2 the mating reaction does not occur at temperatures higher than 25° C. The best reactions occur at temperatures below 20° C. In variety 3, reactions only occur below 27° C. and are best below 24° C. Both Sonneborn ('38) and Gilman ('41) report that the temperature before as well as after mixture is of importance.

Another factor of importance in some cases is light. This is brought out by the relation of time of day to the mating reaction. Sonneborn ('38b) and Jennings ('39b) have reported on this matter. In *P. aurelia*, Sonneborn finds that variety 1 will conjugate at any time of the day or night; variety 2 will conjugate only between 6 P. M. and 10 A. M.; while variety 3 will conjugate only between 1 A. M. and 1 P. M. It was shown that this is due to light; for cultures of variety 3 kept for 5 days in darkness conjugate at any time of day or night, cultures kept for 5 days in continuous light will not conjugate at all. It was shown that the effect is primarily the result of a suppressing action of light and not of a stimulating action of darkness.

Jennings ('39b) found just the opposite effect of time of day on *P. bursaria.* In varieties I and II the mating reaction will occur only from the latter part of the morning up to about 5 P. M. In variety III, it will occur at any time of the day or night. In *Euplotes* (Kimball, '39c) and in *P. caudatum* (Gilman, '41) no diurnal periodicity in the mating reaction has been found. Light is thus a factor of variable importance in the different species and varieties.

Another factor of considerable importance is the time since the last nuclear reorganization (conjugation or autogamy). In *P. bursaria*, the effect is particularly striking. Jennings ('39c, '41c) reports that in some cases no conjugation will occur for many months after a previous conjugation. Finally after this period the exconjugant clones become able to conjugate again. In other cases, such an "immature" period may be of only a few weeks duration. Sonneborn ('38b) reports a period of "immaturity" of six to ten days in some stocks of *P. aurelia.* In other stocks no "immature" period could be detected. As soon as sufficient animals are available for testing,

conjugation can be obtained. Kimball ('39c) reports an "immature" period of about a month in *E. patella*.

Sonneborn ('38b) reports that in *P. aurelia* the mating reaction will not occur with animals undergoing fission, autogamy, or the reorganization stages of conjugation.

Giese ('35, '39) has carried out detailed studies of the environmental factors necessary for conjugation in *P. multimicronucleatum*. As already mentioned he stresses the importance of the food factor. Well fed animals do not conjugate. The proper osmotic relations in the media are necessary. The animals will conjugate in a balanced salt solution or in a sucrose solution of similar osmotic pressure, but no conjugation occurs in distilled water although the animals survive. No appreciable effect of metabolites or of the hydrogen ion concentration from pH 6.0 to pH 8.0 could be detected.

It might be thought that since the nucleus determines the mating type it would have to be present for a mating reaction to occur. However, Tartar and Chen ('41) have shown that this is not so. They find that fragments of *P. bursaria* without any nuclear material will react with each other or with whole animals. In all cases only fragments of different type or whole animals and fragments of different type react. Such reactions never lead to true conjugation, however. Moreover, when fragments were kept overnight during the period when no conjugation would occur, they did not again react the next day when placed with whole animals of a different type. Thus while the nucleus is not immediately essential for the occurrence of the mating reaction, it appears to be essential for true conjugation and for the continuation of the ability of the animals to react with one another.

Boell and Woodruff ('41) have made the only accurate study of the physiological condition of the animals at the time when they are in condition to conjugate. They worked with *P. calkinsi* and showed that the animals capable of giving a mating reaction regularly have a lower respiratory rate than those which are not capable of giving the reaction. When the animals of one of the two mating types have a high respiratory rate and those of the other a low rate the mating reaction but no conjugation results. When animals of both the mating types have a high rate no reaction occurs. It is interesting to note that one of the types (II) has a somewhat higher rate of oxygen consumption than the other under all conditions.

Of the different environmental factors, only the nutritive condition is known to be of general importance. The other factors, while important in particular cases, either have little importance in others or have not been investigated in a sufficient variety of forms. Even the nutritive condition appears a variable factor. In my own experience, it is a factor of great importance in *P. aurelia* where the range of nutritive conditions under which conjugation will occur is very limited. On the other hand, in *P. bursaria* and *E. patella* the range of conditions is much wider. Only very well fed or extremely starved animals of these species fail to react if other conditions are suitable.

Theoretical considerations on the mating reaction

It is too early as yet to attempt to put forward any detailed hypothesis of the mechanism by which mating type diversity brings about conjugation. However, certain facts have been brought out in the preceding discussion that allow some provisional ideas on this matter to be advanced. Jennings' ('39c) description of the mating reaction in *P. bursaria* indicates that the sticking together is the result of a surface "stickiness" and not any coordinated behavior of the animals. He describes the reaction as starting with the accidental contact of two individuals which behave as though stuck together by "some strong adhesive material." At first the contact seems to involve primarily the cilia and only later is more intimate contact established. Thus it seems possible to postulate that some substance or substances on the surface of the cilia and perhaps the body are responsible for the sticking together.

After this first adhesion to one another, other things occur. Probably in this category should be placed the indentation of the body of the animal at the region of contact described by Tartar and Chen ('41). Though the indentation appears at the time of the sticking together, it is difficult to see how it could be directly involved in the sticking. After the first clumping the animals move around on one another until the proper position for conjugation is reached. The primary reaction or clumping appears to be independent of the secondary reactions that lead to final conjugation for the clumping may occur under conditions in which final conjugation does not. Most of the

rest of the discussion will be concerned with the primary reaction, the sticking together.

I have postulated that there is some substance or substances on the surface of the cilia and perhaps the body which are responsible for the sticking together of animals. Since in *Paramecium* only animals of different mating type will conjugate, it is necessary to assume that a different substance is present on animals of each mating type. At this time nothing can be gained by making a more definite hypothesis about the nature of these differences.

Ordinarily these substances seem to be firmly bound to the surface of the animal. However, Sonneborn ('37) made an observation on *P. aurelia* which seems to show that they may sometimes be transferred from one animal to another by contact. He found that animals of the same mating type are capable of forming pairs with one another if one of them had been in contact with an animal of a different type. These pairs do not persist so that no true conjugation is involved but only the primary reaction or sticking together. It seems probable that some of the substance is transferred from one animal to another thus making the animals capable of sticking to others of their own type.

In *Euplotes patella* a little more is known about the mechanism of mating type action. As has been previously said, animal-free fluid from cultures of animals of one type will induce conjugation among animals of other types. While some sort of substance active in conjugation has thus been shown to exist in the fluid, the evidence for an adhesive material on the surface of the animal is not as strong as it is for *Paramecium*. There is no immediate clumping together of animals when different types are mixed, and in general the sticking together is much less violent and rapid than in *Paramecium*. Nonetheless, the animals do finally stick together in pairs so that it seems not improbable that some substance is present on the animals' surface which is responsible for the sticking.

If we assume that such substances do occur in *Euplotes*, the question arises what relation they have to the substances that have been shown to exist in the fluid. It is conceivable that the substances in the fluid are adsorbed onto the surface of the animals, and there take a direct part in the sticking together of the animals. This is a tempting view since it makes it possible to put the *Paramecium* and *Euplotes* work into the same scheme. In *Paramecium*, the substances responsible for sticking have been assumed to be rather firmly bound to the surface of the animal, only coming off by direct contact with another animal. In *Euplotes*, on this view, the substances would not be firmly bound to the surface but would be set free into the medium from which they could be adsorbed and take part in conjugation.

Another view of the action of the substances in the fluid in *Euplotes* may be taken, however. It may be assumed that they merely induce the formation of substances on the surface of the animals and that these latter substances are responsible for the sticking together of the animals. No evidence that would make possible a decision between this indirect and the direct action hypothesis is available.

I have purposely avoided, in making these hypotheses, any attempt at a detailed formulation of schemes to account for the various mating type systems and the system of fluid interactions in *Euplotes*. A number of such hypotheses could be made, but it seems premature to make such attempts at the present time.

The connection between the mating reaction in ciliates and phenomena involving sticking together of cells in other organisms deserves a short discussion. The results of mixing gametes of different sexes in certain of the flagellates has been studied by Moewus ('39). A superficial resemblance to the mating reaction is found since the gametes at first stick together in large masses which later break down into copulating pairs. However, Moewus has shown that the gametes come together as a result of a chemotactic response. Nothing is known of the factors involved in the actual sticking together of the cells so that these studies of Moewus do not help us with the problem of sticking together in the mating reaction of ciliates.

The studies of fusion of sperm and egg in metozoa eventually may give some help in solving the problem of fusion in the ciliates. The investigation of the sperm agglutinating agent, fertilizin, by Hartmann *et al.* ('40), by Tyler ('41), and by others, reveals a situation which has a certain resemblance to that in *Euplotes* in that substances in the fluid bring about a sticking together of cells. However, no resemblance to the situation in *Paramecium* can be seen, and the resemblance to that in *Euplotes* is not great.

The phenomena involved in agglutination of blood cells are of somewhat more interest. As far as the mating reaction in *Paramecium* is concerned, there seems to be little similarity since there is nothing in the mating reaction in this genus to compare with the action of the serum in producing agglutination of cells which are all of the same kind. In *Euplotes*, on the other hand, substances in the fluid do cause sticking together of animals which are quite possibly all of the same kind. As a matter of fact, a system of agglutinins and agglutinogens can be postulated for *Euplotes* to explain formally the interactions of fluid and animals. It is too early to say whether this system can be considered to be anything more than a formal explanation.

I now want to bring together into a general scheme what has been said in this section. The reactions leading to conjugation can be broken up into three major steps; the formation of substances which are responsible for the sticking together, the sticking together of the animals, and the series of changes in position and so forth that lead to final conjugation. What factors have been found that affect these various steps?

Animals of each mating type must have a different substance or substances on their surface. This difference in the kind of substance produced must be under the influence of those factors, primarily genic, which determine the mating type. In addition to factors which determine the kind of substance, there are other factors which probably determine whether any substance at all is produced. Thus it seems probable that immature clones do not produce any substance. This is certain as far as the substances in the fluid in *E. patella* are concerned, for fluid from an immature clone will not induce conjugation among animals of a mature clone. It seems probable that the nutritive condition also affects the production of the substances. Animals which have recently exhausted a considerable supply of food are in the most favorable condition to conjugate. At this time a change in the metabolic condition from one in which the animals are utilizing an abundant supply of food to one in which they are drawing on their own stored resources has occurred. It seems not improbable that the products of metabolism including the substances responsible for conjugation are different in these two phases. Genetic factors also play a rôle in determining whether any substance will be produced since different stocks or species differ considerably in their response to the factors of nutrition and maturity.

Little is known of factors which can with any degree of certainty be said to affect the sticking together process itself. Of course, it is necessary that animals of different mating types be present or at least fluid from one type and animals of another. It is possible that temperature and light affect this stage in the process, but it would be equally possible that they affect the formation of the substances. As with nutrition and maturity, the sensitivity to temperature and light differs with different stocks and species so that genetic factors must be involved.

The final step in the reaction, the various changes which lead from clumping to final pairing, can be differentially affected by certain environmental agents so that it does not occur although preliminary clumping does. The details of this have been given above. From the various published reports it seems that temperature, light, and nutrition all affect this stage in the conjugation process. Again genetic factors are also involved since different stocks and species are differently affected by some, at least, of these factors.

The discussion in this section has been to a large extent theoretical. Nonetheless it will, it is hoped, serve to show that it is possible to begin to correlate the various facts about the mating reaction and to fit them into a scheme which, though still very generalized and vague, may serve as the beginnings of a working hypothesis. The work on the factors involved in conjugation, and in particular the mating types, has its greatest significance in that it allows an approach to the problem of gene action in material readily amenable to various types of experimental treatment and in that it presents the possibility of investigating the rôle of sexual isolation in evolution.

Addendum

Since this paper went to press Sonneborn has reported (*Anat. Rec.*, 84: 542) the existence of four more non-interbreeding varieties in *Paramecium aurelia*. In each of three of these varieties two mating types have been found but in the fourth so far only one. In a second abstract (*Anat. Rec.*, 84: 542–543), he reports a mutant clone which is able to give a typical mating reaction but is unable to go ahead and fuse in con-

jugation. From this he concludes that the mating reaction and the processes leading to final conjugation are controlled by different mechanisms. From the fact that a type II animal will behave temporarily as of type I when it has been in contact with a type I animal, he concludes that some substance may be transferred from the surface of one animal to that of another.

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THE DETERMINATION OF THE CASTES OF SOCIAL INSECTS (*Concluded*)

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THE INCIPIENT COLONY

IN THE incipient colony social complexity is at a minimum and environmental conditions are likewise simple. It seems significant, therefore, that sterile castes and only sterile castes develop in the incipient colony. At least one soldier is present in the first broods of all termites the development of whose incipient colonies is known, including representatives of the three major families (Oshima, 1919; Heath, 1927; Kalshoven, 1930; Castle, 1934; Pickens, 1934, 1943), and it may be assumed that this is true of all other species possessing soldiers. Goetsch (1939) has even reported the development of soldiers in incipient colonies of *Anoplotermes*, for no one of whose many species have soldiers been found. Whether these prove to be soldiers of *Anoplotermes* or not, they furnish another example of the occurrence of soldiers in first-brood colonies. Heath believes that the entire first brood of *Zootermopsis*, indeed the entire first three or four broods, are nymphs in the soldier line, and he actually terms the nymphs of these broods soldiers until they acquire wing pads. In the incipient colonies of the two higher families so far studied the entire first brood develop into sterile individuals, one or a few becoming nanitic soldiers, and the remainder nanitic workers (Oshima, 1919; Pickens, 1934, 1943).

Further, no individual of the first brood of the incipient colony of any species of termite is known to develop into an alate or even, under ordinary conditions, to develop wing rudiments, which would indicate development in the alate direction. In the lower termites, alates develop late in the life of the colony (Heath, 1927; Kalshoven, 1930), and there is no evidence of their occurrence in any species, in colonies founded by a single primary pair, earlier than two years after the founding of the colony.

If an extrinsic control of caste determination be postulated, one must conclude, therefore, either (1) that just here, in the milieu presented by the incipient primary colony, are to be found especially represented the factors or conditions needed to bring into action the genetic mechanisms which determine the sterile castes, those which determine the reproductive caste being lacking, or (2) that something in this milieu inhibits development along the alate line, and therefore allows the development of sterile castes. In addition, there must be some mechanism which in higher termites determines typically one or a few of this group as soldiers and the rest as workers, or, in lower termites, one as the only soldier to appear during the first year, and that in a much earlier instar, the fifth, than in the older colony, where the soldier is in the eighth, ninth, or even the tenth instar.

Here in the incipient colony should lie, therefore, the most promising field for an analysis of factors directing the development of the castes. Its availability is enhanced by the practical considerations that the incipient colony is hardy and lends itself to laboratory culture. Although first broods can be reared satisfactorily in the laboratory, it must be emphasized that no success has been attained in carrying these colonies through the second year. Kalshoven and Heath were able to do this only by resorting to field conditions or an approximation of them, and there is reason to believe that many of Kalshoven's older colonies were far from normal.

Castle (1934) was the first to use these first brood colonies with their single precocious soldier in an attempt to detect the nature of the mechanisms which regulate the occurrence of sterile castes.

My experiments have involved some thousands of incipient colonies, chiefly of *Zootermopsis nevadensis*. These colonies have been set up at various times of the year, from alates of varying degrees of

physiological maturity and from colonies with various histories. They have been cultured, furthermore, by various methods and under varying laboratory conditions. The uniformity reported by Castle with relatively few colonies and under essentially uniform conditions is lost, but my findings in general confirm his. Under optimum conditions so many first broods produce a soldier that this may be considered to be the normal condition, and any deviation from it due to unfavorable circumstances. In one large series in which the alates appeared to be in an especially favorable condition, at least 95 per cent of the colonies not used for experimental purposes produced a fifth instar soldier, and, indeed, many of those variously altered and disturbed by experimentation also produced such soldiers.

Among the thousands of incipient colonies cultured there were, of course, many in which no soldier was produced in the first brood. In many instances it was obvious that this failure was due to the poor condition of the alates or to abnormalities in their life cycle. In other instances, physical conditions in the culture jars were unfavorable, especially with regard to moisture and food supply, or there was incidence of disease. Disturbing the colonies by changing containers usually resulted also in a decline of the colony. No doubt the vast majority of incipient colonies in nature are as imperfect as many in the laboratory, and die out as do they.

If the obviously subnormal colonies are disregarded, approximately 80 per cent of the remaining hundreds of incipient colonies which were not used for experimentation gave rise to the fifth instar soldier under laboratory conditions. Other conditions remaining favorable, therefore, those experimental series in which considerably less than 80 per cent of the colonies produced soldiers are considered as demonstrating an inhibiting effect by the factor under investigation. This would seem the more justified since only obviously flourishing colonies were chosen for use in experimental series. The significance of less striking deviations is dubious.

That our evidence is much less clear-cut and conclusive than Castle's is due, in part, no doubt, to our much more numerous experiments, to their wide seasonal range, to the many different culture methods used, and to a much greater range in the origin and condition of the experimental material used. There seems reason to believe that the differences may be due in part, also, to the fact that different species were used. Castle used *Zootermopsis angusticollis* and we, *Z. nevadensis*. The latter species is more pugnacious and there is evidence that incompatibility influenced experimental results.

Castle found that half of the single series of 12 incipient colonies from which he removed the first soldier gave rise to a second soldier, whereas with us this was the case in 31 out of a total of 247 colonies of varying origin and treatment, or in about 12.5 per cent of the colonies. Four of our 31 colonies which produced second soldiers were known to have produced also a third soldier after the second was removed, whereas Castle obtained more than two soldiers in 2 of the 6 colonies producing second soldiers, and in 1 colony as many as six soldiers were produced.

Definite results were obtained in our experiments with regard to the inhibitory effect of introducing a soldier into the incipient colony, completely confirming Castle's findings. Of 123 colonies into each of which we introduced an ultimate soldier nymph (pseudo-soldier of Castle) only 5 colonies, or 4 per cent of the series, produced soldiers of their own. All the colonies were chosen as flourishing colonies and nearly half of them were from a series of colonies close to 100 per cent of which produced soldiers under favorable conditions. It seems safe to state, therefore, that except for the presence of the single introduced soldier nymph a soldier would have appeared in each of at least 100 more of these colonies.

Four of the five soldiers produced were in colonies in which the introduced soldier nymph had died and been replaced at least once. In the fifth colony which produced a soldier there was no replacement of the originally introduced soldier, indicating that the latter had been accepted and fed. In this colony, however, the first soldier was not produced until 42 days after introduction of the soldier, and when the soldier produced by the colony was removed while yet in soldier nymph form, another soldier was produced, 122 days after the first one and still in the presence of the introduced soldier. This long delay may indicate a continued low inhibitory effect.

When soldiers from older colonies, or even fifth instar soldiers (instead of soldier nymphs) from incipient colonies were introduced into incipient colonies of *Zootermopsis nevadensis*, results were very different from those obtained by Castle for

Z. angusticollis. The usual result was either the destruction of the colony by the soldier or the walling off of the soldier by the colony and its consequent death within a week. Five out of 8 of the colonies in which the latter occurred produced their own soldiers. In only 1 colony out of 20 was the soldier seemingly accepted. Here 19 days after the introduction of the soldier a soldier nymph appeared in the colony.

In our experiments with *Z. nevadensis* all recipient colonies contained nymphs well along in the first instar, and about half of them contained second instar numphs. In Castle's experiments with *Z. angusticollis* the recipient colonies were still older, with third instar nymphs. Thus, for *Z. angusticollis* at least, the inhibition is shown to be possible to within a short time before the soldier nymph would be expected to appear.

Laboratory difficulties prevented conclusive results in attempts at inhibiting soldier production by other methods involving the influence of soldiers. Thus dead soldiers were simply avoided, and 17 of 20 colonies into which they were regularly introduced produced their own soldiers. Soldier extracts were violently toxic or, when reduced to non-toxic concentrations, were ineffective. Attempts to test the inhibiting influence of the materials left in jars by soldiers resulted in excessive mortality, presumably because of the laboratory procedures involved and experiments designed to test an inhibiting effect from odors from soldiers gave inconclusive results.

Castle reported that the production of soldiers was prevented in 5 primary incipient colonies into each of which 10 older nymphs were early introduced. In the broods thus produced he found the early stadia so greatly lengthened as to furnish an explanation of the failure of the fifth instar soldier to appear within the year. We did not repeat this experiment but introduced single nymphs of various types into colonies in later stages of development in a search for critical periods and minimum requirements for inhibition. Results are summarized in Table 3.

Keeping in mind that at least 80 per cent of incipient colonies not obviously abnormal produce soldiers, these results would seem to indicate that the relatively late introduction of single older nymphs of certain types prevents the development of a soldier in some colonies, but not in all. Most of the soldiers produced appeared within a few weeks after introduction of the foreign nymph. In these groups there was no indication of inhibition, therefore. It was not determined whether the stadia were lengthened in those colonies which did not produce soldiers.

The data suggest that certain nymphs have little or no inhibitory effect. This was true of the fourth instar nymphs and the female apterous seventh instar nymphs. (It should be noted that we termed apterous any nymph lacking wing pads obvious to the naked eye. No doubt some of these possessed wing rudiments or wing vestiges.) The wing-padded nymphs and the female broad-headed nymphs, on the other hand, did seemingly

TABLE 3

Effect on soldier production in primary incipient colonies of introducing a single nymph when colonies have several first instar nymphs and some have a few in the second instar

TYPE INTRODUCED	NUMBER OF GROUPS	NUMBER PRODUCING A SOLDIER	PER CENT PRODUCING A SOLDIER
Wing-padded sixth instar	10	5	50
Wing-padded sixth instar	13	3	23
Female, broad-headed, eighth instar	20	6, 9*	30, 45
Female, wing-padded, seventh instar	18	10	55
Totals for those showing inhibition	61	24, 27	37, 44
Female, apterous, seventh instar	20	14, 15**	70, 85
Fourth instar	10	8	80
Expected if no inhibition			80–100

* Three colonies produced delayed soldiers after 93–160 days.

** One colony produced a delayed soldier after 123 days.

inhibit soldier production in some of the colonies into which they were introduced. These findings, while suggestive, require to be confirmed by more extensive and more definitely controlled experiments.

Our experiments included many which involved the removal of the first brood at various stages of its development. The results, although not so clear-cut as Castle's, are in general agreement with them. Removal of the first brood in some way stimulates the pair to produce a second brood, and this second brood tends to include a single nanitic soldier, as did the first. The soldiers thus produced are in the fifth instar and they appear in

enough colonies to indicate that the factors operating here are similar to those in the first brood.

Heath (1931) reported that functional supplementary reproductives of *Zootermopsis angusticollis* isolated in groups of five gave rise to incipient colonies similar to primary incipient colonies. We have carried this a step further by setting up isolated pairs of functioning supplementaries. Of the 70 pairs which produced young, at least 8 produced fifth instar soldiers, and one of these produced a second soldier after removal of the first. Again, in connection with the study of parthenogenesis, to be reported later, it was found that virgin female primaries (alates) set up two or three together or singly proceeded to produce a first brood. Out of one series of 21 female primary couples which produced young, 7 were known to have produced a soldier, and out of another series of 16 such couples, 3 produced soldiers. Of 8 single females which produced young, one colony was known to have had a soldier. In all these cases the soldier produced was the nanitic fifth instar soldier characteristic of the normal incipient colony. The conditions necessary to the production of the nanitic soldier must have been present, therefore, in these exclusively female parthenogenetic colonies, as also in the normal primary incipient colony and the supplementary incipient colonies. The low percentage of colonies producing soldiers in the case of exclusively female and supplementary incipient colonies is presumably due to unfavorable conditions connected with the abnormality of such situations. In nature supplementaries do not found new colonies, nor do female primaries do so without the presence of males. While, therefore, it is not possible as yet to say what actually does cause the appearance of the nanitic first-brood soldier, progress toward that end has been made by the method of exclusion. The appearance of the nanitic soldier:

(1) Is not confined to the progeny of primary reproductives.

(2) Is not dependent upon fertilization of the soldier-producing egg (although the uniparental soldiers are exclusively female and presumably diploid).

(3) Is not dependent upon the presence of either one or both of the founding reproductives. It may occur some time after the male parent, the female parent, or even the pair of reproductives has been removed from the colony; indeed, even after some of the first brood have become supplementaries following removal of the founding pair.

(4) Is not confined to the first egg, the first nymph hatched, or the first nymph reaching third instar. As will be shown later, the soldier appears in colonies from which the first two eggs have been removed, and in the situation referred to in (3) above, the soldier produced is a fifth instar soldier, but it arises from one of the younger nymphs of the brood, the older nymphs having reached the fifth or sixth instar.

The appearance of the nanitic soldier might be thought to be determined by the size of the group, but certain other findings are difficult to explain on this basis. One is the fact that soldiers are often produced in colonies of very few individuals, in some instances, even, a single nymph became a soldier. Again, on combining first broods of two colonies of the same age, not only were there no instances of two soldiers in any combined group, but the number of soldiers produced fell below that expected of the respective recipient colonies. There were 27 donor and 27 recipient colonies. Left alone, they would have been expected to produce 50 or more soldiers. Combined, they produced only 15, never more than one to a colony. From 7 of these 15 colonies, the soldier nymph was removed. Here, if ever, the production of a second soldier would be expected, yet in no instance was another soldier produced.

One might think that the increased size of the group was involved in the inhibition in the combined broods. However, when we combined the nymphs of numerous small broods which had been produced by isolated supplementary pairs and in which a soldier had not appeared at the expected time, a number of soldiers appeared. Moreover, these soldiers were nanitic, although nymphs of older instars were present. In the most striking instance, some 90 young nymphs from 55 different supplementary pairs were placed with a single supplementary pair. To our surprise, some 50 days later there were 7 nanitic soldiers. Two weeks later there were 13, and still another soldier appeared after another week. In a similar although smaller group 2 such soldiers appeared.

More recently the nymphs of incipient colonies were combined and in several of these groups fifth instar soldiers have developed although here also older nymphs were present. One can only speculate as to why nanitic soldiers are produced thus tardily when older imperfect incipient colonies are combined, whereas inhibition results from a combination of younger broods previous to the expected

time of soldier production. The significant difference may well be one of chronology.

Ordinarily it seems to be the oldest nymph, presumably derived from the first egg, which gives rise to the first brood soldier. Numerous experiments were designed to determine whether only the first egg could give rise to the soldier or whether any other one or all of the eggs of the clutch possess this potentiality. Eggs were shifted in various ways between colonies. Laboratory difficulties rendered most of these experiments inconclusive, but it can be said that in some of the groups from which the first egg or the first and second eggs were removed soldiers appeared. Thus, of one series of 18 groups from which the first and second eggs were removed at least 5 groups produced the usual nanitic soldier. Evidently eggs other than the first are capable of developing into soldiers, presumably all of them. It is not clear whether the low percentage of colonies producing soldiers in this series relates to the absence of early eggs or the handling and disturbance involved.

REPRODUCTIVES

The distinctive reproductives of the termite colony and the ones most commonly encountered are the primary reproductives. They are fully pigmented and sclerotized individuals, with well-developed compound eyes. In the early portion of their adult life they bear large well-developed wings and hence are known as alates. Alates develop seasonally in large numbers in all mature colonies.

These alate primaries function in the dissemination of the species and the founding of new colonies. A flight from the colony of origin occurs seasonally, its timing determined by humidity and temperature conditions. The flight is followed immediately by dealation; the wings break off along a well-defined suture. Only the wing bases remain to indicate the alate origin of dealates, as the primaries are now called. Pairing follows hard upon delation and is succeeded by a search for a favorable site and the excavation of the primary cell of the incipient colony. Functional sexual maturity is not attained until some days after pairing. As the colony enlarges, gonadial hypertrophy in the founding pair results in differing degrees of physogastry. The abdomen of an old queen of the fungus growers is relatively enormous.

The primary reproductives, known at different stages of their adult life as alates, dealates, and kings and queens, form a single caste. They are the only perfect individuals of the species, retaining most nearly the ancestral characteristics of the group. It is from an originally homogeneous population of such individuals that we must trace the phylogenetic origin of the other castes.

Most new colonies are founded by a single pair of primary reproductives and this pair usually heads the colony throughout much if not all of its life as a colony. In some species of higher termites the primary is the only type of reproductive known. In most species carefully studied, however, including species of each of the three large families, an additional type of reproductive is encountered, the so-called supplementary reproductive (*Ersatzgeschlechtstier*, substitution, replacement, or complementary reproductive). In general it may be said that these show nymphal characteristics in varying degree. In almost all species they lack the strong pigmentation of the primary reproductives, but they are more deeply pigmented than the nymphs and usually more so than workers when these are present. The compound eyes and wings likewise are never present in perfect expression and may be rudimentary in varying degree, or entirely lacking.

Great differences obtain between genera and species as to the frequency with which supplementary reproductives occur, their numbers in the colonies in which they do occur, the form they usually take (Emerson, 1933), and the conditions under which they occur. Thompson and Snyder complicated the picture by attempting to distinguish between three separate, intrinsically determined reproductive castes, namely, first-form reproductives (macropterous, or primary, reproductives), second-form reproductives (brachypterous, or wing-padded, supplementaries), and third-form reproductives (apterous supplementaries). In spite of a great accumulation of evidence against the existence of different castes of reproductives, or even of the intrinsic determination of castes in general, this terminology with its confusing implications persists in the literature.

Pickens, working chiefly with *Reticulitermes hesperus*, found, as had Grassi and Sandias in *R. lucifugus*, that the supplementaries correspond in size and structure to all nymphal instars above the third, as also to the immature alate. Heath, and later Castle, found the same situation to hold in *Zootermopsis*, and my findings have increased the range of structural types known to occur among the supplementary reproductives.

Castle showed that the development of supplementaries cannot be due to special feeding, since isolated nymphs undergo changes in the direction of gonadial hypertrophy (although they never become pigmented nor have they been known to lay eggs). Furthermore, his findings, amply confirmed by me, show that nymphs paired at random and kept as isolated pairs do become pigmented and reproduce. This could not be construed to result from special feeding unless each individual is supposed to be able to administer the hypothetical specific stimulating diet to any nymph of the other sex when isolated with it. Neither can it be a genetically determined tendency limited to a certain number of nymphs, since nymphs chosen at random show the possibility. Many thousands of experiments with groups of nymphs throughout the years have convinced me that, as Castle (1934b) says, "All members of the colony except the true soldier are potentially reproductive and, with the exception of the wing-padded nymph of the late seventh instar and the first form reproductive, can develop into supplementary reproductives in the proper environment. Supplementary reproductives are examples of neoteny." This tendency on the part of nearly all nymphs of any colony of most species of termites to become precociously sexually reproductive (neotenic) I have termed reproductivity for convenience of reference. Studies on the rate and extent of reproductivity have been carried out under varying conditions and are briefly reported below.

Since supplementary reproductives are merely neotenics, it is better not to consider them as representing a caste or castes, but simply as individuals which have undergone a precocious sexual development with structural fixation in whatever stage they may have reached at the time. However, we must think of this tendency toward neoteny as present in every young nymph, and in most others, and as offering an additional developmental route alternative to that leading to the alate condition or that leading to the soldier state (or to the worker state, where such exists), and leading to it from almost any point along any of the alternative lines or, indeed, a combination of them. The last emendation is necessary since we obtain not merely soldiers with well-developed wing pads, intercastes, if you will, between the soldier and primary reproductive castes, but also individuals of this type which have in addition well-developed functional gonads. The female individuals of this last type give rise to a seemingly normal progeny. We have here, then, individuals showing definite persistent structural indications of having developed at the same or different times under the influence of all three of the directing mechanisms found in *Zootermopsis*, namely, that leading toward alate development, that toward soldier development, and that toward precocious sexual maturity. The result is a neotenic alate-soldier intergrade.

The question is, What is the regulating mechanism which ordinarily prevents the operation of the mechanism for precocious gonadial hypertrophy, obviously present in most nymphs? Put more artificially in terms of reproductivity, What is the mechanism which reduces expressed reproductivity to zero in most wild colonies?

Clearly, inhibition of reproductivity is tied up with the presence of functional reproductives. When functional reproductives are removed from a colony, one to many nymphs of the colony very shortly show signs of development as supplementaries. Pickens, finding this to be the condition in *Reticulitermes hesperus*, as had Grassi and Sandias, Jucci, and others for other species, proposed the theory (1932) that the inhibition was accomplished by means of a chemical substance or substances produced by the functioning reproductives and obtained and distributed throughout the colony by communal relations.

Castle (1934a, b) holds that control (or inhibition) is completely unilateral: that only male nymphs develop into supplementaries when female reproductives are present and male reproductives absent, and vice versa.

The inhibition arising from the presence of functioning reproductives we have termed, for convenience, contact inhibition, and a number of experiments were carried out with a view to obtaining quantitative evidence, first, for the existence and extent of such inhibition in general, and, secondly, for the unilateral nature of the inhibition. Space does not permit presentation of the evidence in detail. However, several general statements can be made, and samples or summaries of the evidence given where this lends itself to brief presentation.

(1) *Contact inhibition varies widely in effectiveness, ranging from complete inhibition under most natural conditions to a very imperfect inhibition in many laboratory groups.*

Among our thousands of primary incipient colonies there is but one doubtful record of the development of a supplementary among the offspring

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while the founding pair remains. When the pair dies, however, or is removed, supplementaries develop among the offspring so commonly as to indicate that it would occur in all orphaned colonies under favorable conditions (see Table 4).

A very high percentage of wild colonies found headed by primary reproductives (a pair in all instances in *Zootermopsis*, presumably the founding pair) contain no supplementaries. Many of these completely inhibited colonies are old colonies consisting of several thousand individuals. So consistently have the colonies headed by primaries been found to lack supplementaries that we are led to suspect that the few seeming exceptions are due to mixture during removal of two colonies headed,

TABLE 4

Occurrence of supplementary reproductives in incipient colonies when primaries have been removed

REMOVED	NUMBER OF COLONIES	OBSERVED AFTER	RESULTS
		(*days*)	
Pair.....	20	82	19 colonies with pigmented indviduals, the other with eggs
Female.....	20	103	13 colonies with pigmented females, 1 also with pigmented male
Male.....	20	103	11 colonies had pigmented individuals, 3 had one pigmented female only

respectively, by a founding pair and by supplementaries.

Wild colonies headed by supplementaries may contain from a few to several hundred supplementaries but the number is always relatively small in proportion to the number of individuals in such a colony which are capable of becoming supplementaries. That is, these colonies also exhibit contact inhibition.

In small laboratory groups contact inhibition by functioning supplementaries is variable and not always strongly effective (Tables 5, 6, 7). The number of supplementaries produced in such groups, although considerable, usually from 3 to 8 of an original 20 individuals in 13 to 18 weeks, almost never includes all of the available nymphs. (It must be strongly emphasized that there is very great variation both as to rate and extent of reproductivity between different groups or series of groups, whether they contain functioning reproductives or not.)

The number of supplementaries produced by a group with or without supplementaries does not depend upon the number remaining alive. Some groups of which a small number remain alive produce more reproductives than do larger groups (see no. 5 in Table 11). Scatter diagrams show no

TABLE 5

Contact inhibition by marked supplementaries

	NUMBER OF GROUPS OUT OF 20 WHICH HAVE PRODUCED SUPPLEMENTARIES BY THE GIVEN WEEK						
Weeks after setting up	2nd	3rd	4th	6th	8th	12th	24th
Controls: no reproductives present	4	10	18	20	20	20	20
Experimentals: functioning reproductives present	2	5	6	9	11	12	16

TABLE 6

Contact inhibition by marked supplementaries

(Same series as in Table 5)

	TOTAL NUMBER OF SUPPLEMENTARIES PRODUCED BY WEEKS DESIGNATED						
Weeks after setting up	2nd	3rd	4th	6th	8th	12th	24th
Supplementaries produced in controls starting without reproductives.....	5	17	52	77	79	79	84
Additional supplementaries produced in experimentals.....	2	6	13	20	23	26	40
Total supplementaries in experimentals.....	61	65	71	78	80	82	93

general correlation between reproductivity and mortality or viability.

Groups originally of the same size, origin, and constitution tend to end up with about the same number of supplementaries, whether they started with supplementaries present or not, although of course groups which start with supplementaries give rise to much fewer new supplementaries (Table 6). Each group reaches a plateau beyond which reproductivity is low and sporadic. The plateau is arrived at early when the rate of repro-

ductivity is high, usually by the sixth week (Table 6).

The unpigmented nymphs in groups in which the plateau has been reached are supposedly inhibited by the supplementaries produced within these groups. If now these supposedly inhibited nymphs are reassembled in groups of 20, without supplementaries, the process is repeated and several of them become supplementaries, showing that it is inhibition, not lack of capacity, which accounts for their previous inactivity. The "control" series of Tables 5 and 6 is such a reassembled series, and the "experimentals" is a series in which the previously produced supplementaries are left in the groups, which are brought up to 20 by adding unpigmented nymphs from other such groups of other series. As will be seen,

TABLE 7

Reproductivity among single nymphs introduced into incipient colonies.

TYPE INTRODUCED	NUMBER OF COLONIES	NUMBER BECOMING SUPPLEMENTARIES
Wing-padded	13	6
Wing-padded	10	6
Wing-padded female	20	2
Apterous female, seventh instar	20	2
Broad-headed female, eighth instar	20	11

the two series reach about the same status as regards numbers of supplementaries present, showing that contact inhibition is far from complete under these circumstances. That far fewer new supplementaries are produced in the groups continuously subjected to the presence of functioning supplementaries demonstrates the reality of contact inhibition here, in spite of its incompleteness. The marked difference in rate of reproductivity between the two series, indicating differences in degree of inhibition, extends over only the early period of the experiment, and both groups reach a plateau with about the same number of supplementaries at about the sixth week (see Table 6).

(2) *Contact inhibition tends to be unilateral but is by no means completely so.*

As will be seen from Table 8, removal of either member of the pair breaks the inhibition and results, in some instances at least, in the production of supplementaries of both sexes, not merely of the absent sex. Table 4 gives similar data from incipient colonies. Grassi long ago noted the same condition with regard to *Kalotermes flavicollis.*

(3) *Contact inhibition seems to be related to the continuous integration of the group and is easily disturbed by laboratory procedures which involve separating the colony from its reproductives, permanently or for any considerable period of time, or dividing the colony into fragments, or disturbing and dislocating*

TABLE 8

Appearance of supplementaries in incipient colonies after removal of one member of primary pair

TYPE REMOVED	NUMBER OF COLONIES	COLONIES WITH SUPPLEMENTARIES	
		After 103 days	After 146 days
Female	20	13 had females, 1 with 1 male also	No record
Male	20	8 had males, 3 had females only	13 had males. The 3 which had had females now had none

TABLE 9

Contact inhibition: The inhibiting effect of reproductives in groups of nymphs of the same number, constitution and treatment

(Only those experimentals considered in which a pair of reproductives persisted)

	WITH PRIMARY REPRODUCTIVES	WITH SUPPLEMENTARY REPRODUCTIVES	WITHOUT REPRODUCTIVES: CONTROLS
Number of groups	11	22	20
Number of groups producing supplementaries	1	4	16
Total supplementaries produced	1	4	35

the colony, in removing it from the log for example, or in setting up experiments.

Primary reproductives effectively inhibit their own progeny, but nymphs introduced into incipient colonies often become supplementaries (Table 7). It may be that this particular failure of inhibition results from antagonism between the introduced nymphs and the reproductives.

The number of supplementaries produced in groups of nymphs is reduced if primary reproduc-

tives are introduced into the groups. This reduction is very striking in some series (see Table 9). Primaries in the laboratory are not much more effective than supplementaries in contact inhibition. Their striking effectiveness in incipient and wild colonies seems to be explained by the unbroken continuity of the relation from the founding of the colony.

MECHANISMS INVOLVED

No attempt has been made to investigate the causes of precocious sexuality. It is presumed, however, that hormonal agents are involved.

As to the inhibiting mechanism, it might be thought to be mediated by any one of several agencies, such as (1) nervous stimuli arising from tactile relations, directly through contact of all nymphs with the reproductives, or indirectly through the behavior of those nymphs which are stimulated by direct contact with reproductives; (2) nervous stimuli arising from odors; (3) physiological reactions set up by special feeding of the inhibited individuals by the reproductives or by other nymphs; (4) differences in the diets of inhibited individuals arising from their feeding certain materials to the reproductives or to the brood; or (5) the action of chemical substances produced by the reproductives and spread through the colony by such communal behavior as (a) reciprocal grooming (discussed by Grassi and Sandias, 1898, p. 20), or (b) proctodaeal feeding (Grassi and Sandias, *op. cit.*, p. 19; Andrews, 1930, p. 458), or (c) stomodaeal feeding (Grassi and Sandias, *op. cit.*, p. 20; Jucci, 1924).

Tactile relations cannot be ruled out, nor does any method of proving their significance suggest itself, except the process of exclusion. Experiments designed to test the efficacy of odors have given no significant results. Indeed, only very striking results would be significant, since contact inhibition is by no means completely effective in small experimental groups.

Differences in food received or given seem to be eliminated as a cause since even single individuals show at least some gonadial hypertrophy when isolated (Castle, 1934a). Further, the fact that supplementaries develop in groups ranging in size from pairs to thousands does not seem to fit in with differential nutrition. Nor does the occurrence of supplementaries have any relation to the presence or absence of eggs or young termites, but only to the continuous presence or absence of functioning reproductives. Their presence could readily be thought to have a significant relation to the food received or given up by the individual in small groups, but hardly so in the large colony.

Castle (1934) reported what seemed at that time a significant delay in egg laying in groups of 50 nymphs of *Zootermopsis angusticollis* fed ether and alcohol extracts of functioning female supplementaries. But my much more numerous experiments with the production of supplementaries in isolated groups of nymphs of *Z. angusticollis* and *Z. nevadensis* show so great a variation in reproductivity as expressed by the time required for egg laying, or by any other criterion, as to render insignificant the delay noted by Castle.

Before information as to the great range in expressed reproductivity was available we carried out experiments to test Castle's findings, and to locate the source of the inhibiting materials. Results of these first experiments are represented as curves for convenience' sake (Fig. 2), as are other similar experiments here reported. These results show that there were great differences in reproductivity between the series fed different extracts. As will be seen, the results seem to indicate a strong inhibitory effect on the part of some extracts, and a weaker inhibitory effect from others, whereas still others seemed to produce no effect at all. The complexity of the theory necessary to explain the varied effects of the different extracts and the unsatisfactory nature of the controls made us doubt the validity of our data, and they were never published. They were presented at scientific meetings, however, and filtered into the literature (Light, Hartman and O. H. Emerson, 1937; Allee, 1938; Emerson, 1939; Gregg, 1942).

Earlier experiments designed to test these first results were unsatisfactory because of high mortality. Such results as were obtained, however, showed a slight trend in the direction of an inhibitory effect. Continued finding of slight inhibition would, of course, be significant if all other factors were eliminated which might account for the differences between control and experimental groups. A rigid investigation of essentially identical groups and series was begun, therefore, in the hope of developing a satisfactory system of controls and of obtaining a measure of the range of variation as to reproductivity to be expected when the constitution of the groups and their treatment were as nearly identical as possible.

One of the obvious points of weakness in the

original experiments (both Castle's and mine) was the fact that controls were not fed extracts of ordinary nymphs. It was thought that the slightly lower reproductivity of the experimental series of earlier experiments might be explained as being due to feeding of extracts of termite bodies, rather than to something peculiar to the reproductives. In later experiments this possible source of error was avoided by feeding controls extracts of unpigmented nymphs (Table 10). It will be noted from the table that little if any difference in reproductivity was recorded in these particular experiments between those fed paper alone and those fed paper impregnated with extracts of unpigmented nymphs. More important than this, of course, is the clear indication of lack of significance of the slight differences in reproductivity recorded for the experimental series fed extracts of functional reproductives. Reproductivity was higher in the experimentals of the first experiment than in the controls, and lower

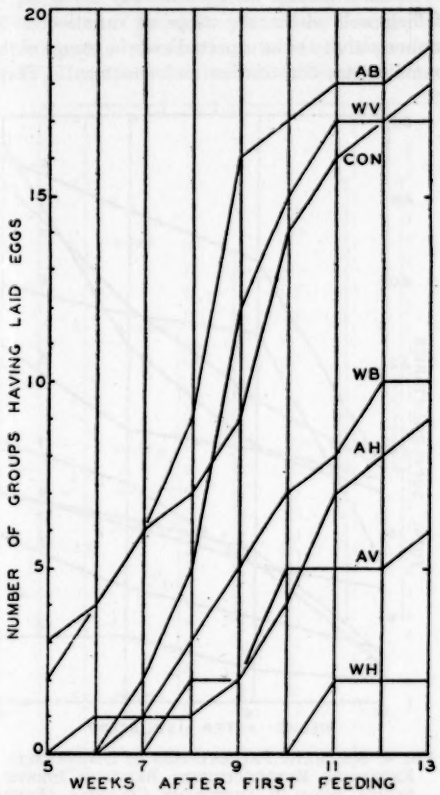

FIG. 2. SCHEMATIC REPRESENTATION OF REPRODUCTIVITY, AS EXPRESSED IN TERMS OF GROUPS WHICH HAVE LAID EGGS, FOR 7 SERIES OF YOUNG UNPIGMENTED NYMPHS SUPPOSEDLY OF THE SAME INSTAR OF ZOOTERMOPSIS ANGUSTICOLLIS BUT FROM DIFFERENT COLONIES AND LABORATORY GROUPS

Each series consisted of 20 groups, each group of 10 nymphs.

Groups of the control series (*Con*) were fed weekly on filter paper. Groups of the other series were fed weekly on filter paper impregnated with water or alcohol extracts of various portions of the bodies of female supplementary reproductives. Reproductivity is expressed in terms of number of groups which had laid eggs at the end of any designated week.

Reproductivity was at least as high in two series as in the controls, namely, in those fed alcohol extract of the body wall (*AB*) and water extract of the viscera (*WV*). It was very low in the series fed water extract of the head (*WH*), and a strong inhibiting effect from this extract therefore seemed to be indicated. Reproductivity was relatively low in the three series fed, respectively, alcohol extract of the viscera (*AV*), alcohol extract of the head (*AH*), and water extract of the body wall (*WB*).

TABLE 10

Effect of feeding ether extracts of supplementaries

DATE OF EXPERIMENT	DURATION OF EXPERIMENT	SERIES	PER CENT BECOMING SUPPLEMENTARIES
	weeks		
October 19, 1941	14	1. Controls (1): fed paper only	13.20
		2. Controls (2): fed extracts of nymphs	13.20
		3. Experimentals: fed extracts of supplementaries	16.40
January 3, 1942	8	1. Controls (1): fed paper only	14.50
		2. Controls (2): fed extracts of nymphs	14.20
		3. Experimentals: fed extracts of supplementaries	11.20
April 15, 1942	9	1. Controls: fed extracts of nymphs	6.00
		2. Experimentals (1): fed extracts of supplementaries	5.77
		3. Experimentals (2): fed extracts of supplementaries	6.00
		4. Experimentals (3): fed extracts of supplementaries	7.77

in the second. In the third the recorded reproductivity of one of the three experimental series was less than that of the control series, in one it was the same, and in the other it was distinctly above it.

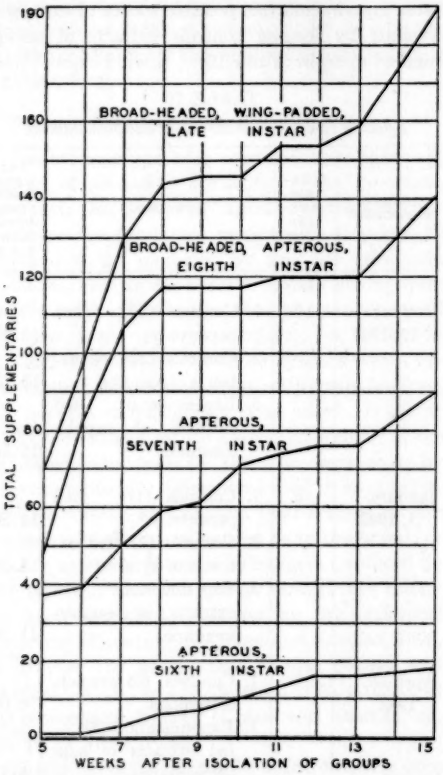

FIG. 3. SCHEMATIC REPRESENTATION OF THE DIFFERENCES IN REPRODUCTIVITY BETWEEN NYMPHS OF DIFFERENT TYPES AND INSTARS

The four series were from the same colony, and were identical as to number of groups per series (40) and number of nymphs per group (10). The series received identical treatment. Each of the series, however, consisted of nymphs of a different type or instar. Reproductivity is expressed in terms of the total number of supplementaries produced by each series at the end of the fifth to the fifteenth weeks. At the end of the fifteenth week the series consisting originally of apterous sixth-instar nymphs had produced only 18 supplementaries, whereas in the series consisting of broad-headed, wing-padded nymphs of late instar, 190 individuals, or nearly half the original population of the series, had become supplementaries.

It may be safely concluded on the basis of these results that the earlier trend toward a seeming inhibition noted above had no significance as regards inhibition and represented mere chance variation or resulted directly or indirectly from unfavorable effects from the extract.

Castle's findings we have already ruled out as falling well within the range of variation as to reproductivity to be expected even in groups of the same origin, constitution and treatment. There

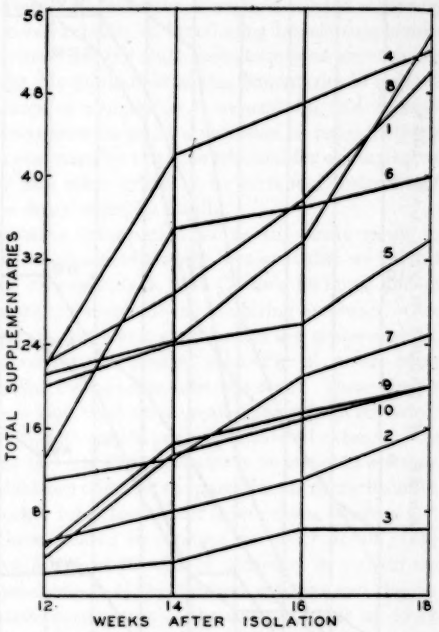

FIG. 4. SCHEMATIC PRESENTATION OF DIFFERENCES IN EXPRESSED REPRODUCTIVITY BETWEEN IDENTICAL SERIES FROM 10 DIFFERENT COLONIES (EXPERIMENT D2)

Each series consisted of 20 groups of 10 nymphs of the fifth instar of *Zootermopsis nevadensis*. The series were set up at the same time and given identical treatment. Reproductivity is expressed in terms of total number of supplementaries known to have been produced in each series by the twelfth, fourteenth, sixteenth, and eighteenth weeks. Note that the series from colony 3 had produced only 6 supplementaries by the eighteenth week, whereas the series from colony 4 had produced 54 supplementaries during the same period.

remain, then, as the only possible evidence for the existence of what for convenience I have termed extract inhibition, the results obtained in the original experiment (Fig. 2). Here it is believed another source of error invalidates the evidence. It was recognized at the time that different instars might have the tendency toward neoteny in different degree and recent experiments demonstrate this strikingly (Fig. 3), but it was assumed that the

same instar in different colonies would be essentially alike as regards potential reproductivity.

As part of an investigation looking toward the development of satisfactory controls, a number of experiments were carried out to test the reproductivity of equivalent series from different colonies. total supplementaries produced by each series at given weekly periods. Each series consisted of 20 groups of 10 nymphs of the fifth instar of *Zootermopsis nevadensis*. Not only are there great variations in the total numbers of supplementaries produced by the different series in a given time

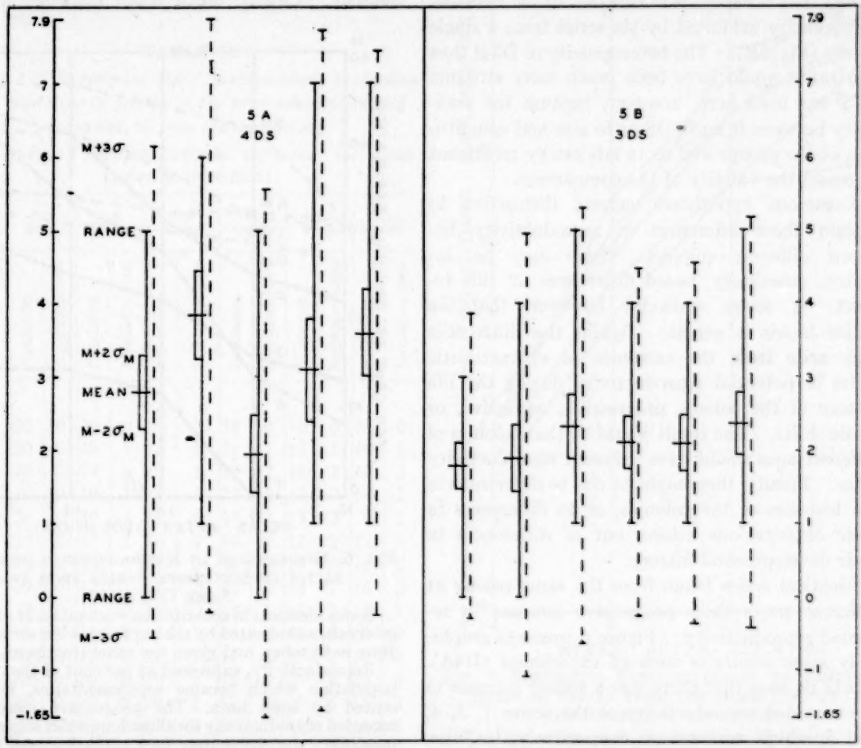

FIG. 5. DICE-LERAAS DIAGRAMS SHOWING RELATIONS AS TO FREQUENCY DISTRIBUTION OF GROUPS, BY NUMBERS OF SUPPLEMENTARIES PRODUCED BY THE END OF THE TWELFTH WEEK, FOR TWO EXPERIMENTS, THE SERIES OF ONE OF WHICH (EXPERIMENT 4DS) ARE FROM DIFFERENT COLONIES (5A), THOSE OF THE OTHER EXPERIMENT (3DS) BEING FROM THE SAME COLONY (5B)

The series each consist of 20 groups of 20 nymphs of *Zootermopsis nevadensis*. The groups were identical within the experiments as to the types and numbers of nymphs. The groups used in the two experiments were of similar though not identical constitution.

As is indicated by the graphic device ($M \pm 2\ \sigma M$), the differences between the means for the series of 3DS (5B) are not significant, whereas there are significant differences between the means of some of the series of 4DS (5A). A similar heterogeneity is seen to exist among the series from different colonies (A) also with the respect to both the recorded ranges and the theoretical ranges ($M \pm 3\sigma$).

The results showed surprising differences between the different series as to rate and extent of production of supplementaries. These differences are so great as to make it seem certain that colonies differ greatly as to potential productivity at any given time. Figure 4 is a graphic representation of some features of one early experiment of this type (D2). Reproductivity was recorded for 10 series, each from a different colony, and is expressed in terms of (Fig. 4), but the frequency distributions of groups within the different series by numbers of supplementaries produced showed great differences. When the frequency distributions are represented diagrammatically for any given week the heterogeneity of the situations in series from different colonies becomes obvious.

Figure 5A is an attempt to represent graphically by means of a Dice-Leraas diagram (see Simpson

and Roe, 1939, p. 316) the heterogeneity of a group of five colonies (Experiment 4DS) as to potential reproductivity as measured by the frequency distribution in the respective series of groups by numbers of supplementaries produced at the end of the twelfth week. The heterogeneity of the results thus obtained is in contrast to the essential homogeneity exhibited by six series from a single colony (Fig. 5B). The heterogeneity of D2 if thus illustrated would have been much more striking. 4DS was used here, however, because the similarity between it and 3DS as to size and constitution of the groups and as to laboratory treatment increases the validity of the comparison.

Numerous hypotheses suggest themselves to explain these differences in reproductivity between different colonies. There may be inherent, genetically based differences in this respect. It seems unlikely, however, that the major factor is genetic. Again, the differences may arise from the existence of characteristic shifts in potential reproductivity during the life history of the colony, progressive, regressive, or cyclic shifts. The result would be that colonies of different ages would have different reproductivity rates. Finally, they might be due to differences in the histories of the colonies, or to differences in their constitutions arising out of differences in their developmental history.

Identical series taken from the same colony at different times show progressive increase in recorded reproductivity. Figure 6 presents graphically some results of such an experiment (D4A). It will be seen that there was a steady increase in the recorded reproductivity of the series 1, 3, 4, and 5, which were set up, respectively, in June, August, September, and October.

These results might be taken as indicating the existence of a progressive shift in reproductivity in all colonies, either seasonal or developmental, or both. Certainly the seasonal developmental cycle in the colony would be enough to cause some change. But that it should be progressive in one direction, as these results seem to indicate, is unlikely, since during the summer and early fall the alates have appeared, matured, and left the colony, and since reproduction is very much reduced, or ceases, during a period of semiaestivation in the summer and again during mid-winter. Finally, it must be remembered that these findings may well represent, in part at least, the results of changes in the colony arising from its use in the experiments. The very removal of the successive groups of nymphs for such an experiment as this successively alters the constitution of the colony, and the disturbance of the colony at the time of the removal of these series would tend in itself to reduce the effectiveness of the mechanism normally inhibiting neoteny. Clearly much more evidence will be required before it is possible to generalize as to direction and extent of shifts in potential reproductivity, or the factors involved and their respective roles in producing these shifts.

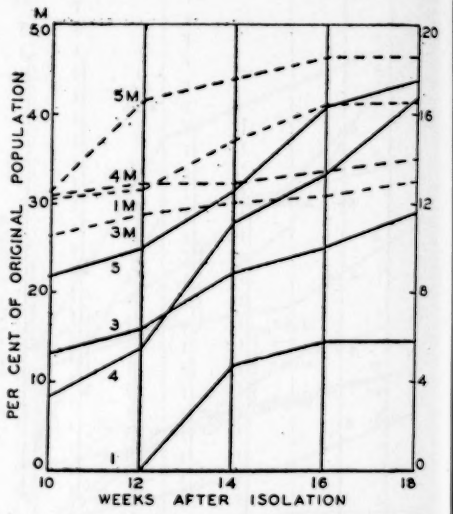

FIG. 6. DIFFERENCES IN REPRODUCTIVITY AND MORTALITY IN SUCCESSIVE SERIES FROM THE SAME COLONY

Series identical in constitution were taken at monthly intervals, as indicated by the numbers of the series, from June to October, and given the same treatment.

Reproductivity, expressed as per cent of the original population which became supplementaries, is represented by solid lines. The progressive increase in recorded reproductivity for these four series suggests the possibility that there may be a cyclic seasonal shift in reproductivity. The increase may be due, however, to the break in inhibition resulting from successive disturbances of the colony. That there is no positive correlation between high mortality in the different series and low reproductivity is clearly shown. Indeed, considered alone, these results might suggest an inverse correlation. Series 5, for example, which has the highest mortality throughout (5M), has also the highest reproductivity.

In the light of the information obtained from experimental results and from general laboratory experience, the following preliminary set of rules has been formulated for experiments on reproductivity.

1. All animals of a given experiment, both controls and experimentals, should be from the same colony and the series should be run concurrently.

2. Colonies used for experiments should be completely inhibited colonies headed by the primary (founding) pair and without supplementary reproductives.

TABLE 11

Series 1 of Experiment 3DS: Supplementary production and mortality in groups of the same constitution and treatment, all from the same colony

(Numbers of supplementaries corrected for those known to have died)

GROUP NUMBER	2ND WEEK		4TH WEEK		6TH WEEK		10TH WEEK		14TH WEEK		17TH WEEK	
	Population	Supplementaries	Population	Supplementaries	Population	Supplementaries	Population	Supplementaries	Population	Supplementaries	Population	Supplementaries
1	20	0	20	0	18	0	18	0	16	0	15	0
2	20	0	18	1	18	1	16	1	15	1	10	1
3	20	0	19	0	19	1	19	2	18	2	15	3
4	19	0	19	1	18	1	18	2	17	2	16	2
5	20	0	20	1	19	1	15	2	13	2	9	2
6	20	0	17	1	16	1	14	1	13	2	12	2
7	20	1	19	2	19	2	17	3	17	3	14	3
8	19	0	17	1	17	2	16	2	16	2	16	2
9	19	0	18	0	18	0	18	1	16	1	15	1
10	18	1	18	1	18	1	14	1	12	1	10	1
11	19	0	18	1	17	2	17	2	15	2	10	2
12	20	0	20	0	19	1	18	3	16	3	16	4
13	20	0	20	1	20	2	17	3	16	3	16	3
14	20	0	18	1	18	1	15	1	15	1	14	1
15	19	1	19	1	16	2	14	2	14	2	14	2
16	19	0	18	0	18	1	16	2	13	2	10	2
17	20	0	20	0	18	0	18	3	16	3	15	3
18	20	0	12	1	disc.		0		0		0	
19	19	0	19	1	17	1	14	2	14	2	14	2
20	20	1	20	1	20	1	19	2	18	2	18	2

3. The experiment should be set up immediately on removing the colony from the log.

4. All groups, controls and experimentals, should be of identical composition as regards numbers and types of nymphs and instars, and should be given identical treatment except for the factor under investigation.

However, even when the precautions listed above are observed, differences in expressed reproductivity between different groups in a series (see Table 11) and also between series supposedly identical as to constitution and treatment (see Fig. 7) still occur. Some of this difference is presumably of the random type to be expected even under the most refined procedures. Some of it, however, and perhaps the larger part, must probably be attributed to a number of variables present in all laboratory experiments with social insects.

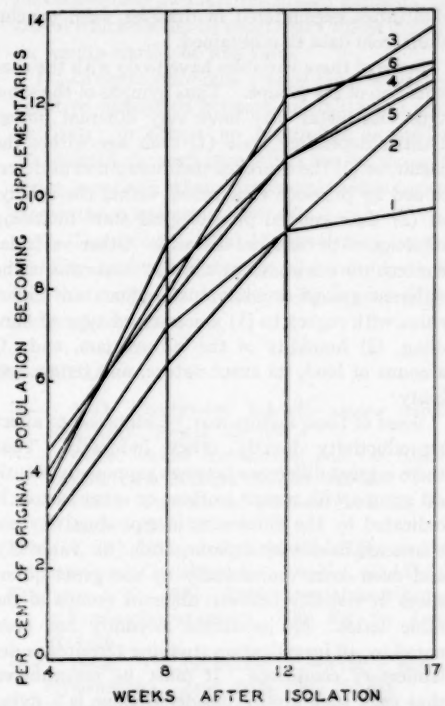

FIG. 7. SCHEMATIC REPRESENTATION OF REPRODUCTIVITY IN SERIES FROM THE SAME COLONY OF ZOOTERMOPSIS NEVADENSIS

The six series each consisted of 20 groups of 20 nymphs of *Zootermopsis nevadensis*. The groups were of identical constitution as regards various types of nymphs included. The series were set up at the same time and given identical treatment. Reproductivity is expressed in terms of per cent of original population of series which had become supplementaries at the end of the fourth, eighth, twelfth, and seventeenth weeks.

It will be noted that the extent of the differences between these series from the same colony is much less than between the series from different colonies (cf. Fig. 5A, 5B). Their similarity is best shown by the results from the fourth to twelfth weeks. The seemingly significant shifts in relative reproductivity in series 1 and 6 between the twelfth and seventeenth weeks are to be correlated with undetermined differences in treatment and constitution, and are epmhasized by the increasing senescense of the groups (see Table 11).

These variables are largely uncontrolled by current techniques; nor have their effects been successfully identified and evaluated. While these factors operate to some extent at random, they add to the difficulties encountered in drawing valid conclusions from data thus obtained.

Some of these variables have to do with the constitution of the groups. Thus nymphs of the same type and instar may have very different potentialities depending upon (1) their age within the instar, or (2) the degree of their inhibition as determined by previous experiences within the colony, or (3) their general physiological state including infection with bacterial diseases. Other variables concern the environment and the treatment of the different groups or individuals. Such are differences with regard to (1) amount and type of handling, (2) humidity of the culture jars, and (3) amount of food, its exact nature, and its accessibility.

Some of these factors may be supposed to affect reproductivity directly, others indirectly. That there is great difference between supposedly identical groups with regard to these or other factors is indicated by the differences in reproductivity encountered in all such experimentals (see Table 11), and even more dramatically by the great differences in viability between different groups of the same series. An inevitable mortality has been noted by all investigators studying termites under laboratory conditions. It must be remembered that each such group considered alone is a dying group, as is of course any non-reproducing population. The rate of mortality varies enormously from a very few individuals out of 20 during 17 weeks (see no. 20 in Table 11) to complete extinction of the group early in the experiment (no. 18, Table 11). The rate of mortality is obviously abnormally high for the species in most of these groups and must indicate unfavorable factors in the original circumstances of the group, its constitution, or its experience during the experiment, or in all of these.

Since differences as to reproductivity (the rate and extent of development of supplementary reproductives) between the control series and the experimental series furnish the only measure of the inhibitory effectiveness of any factor to be tested, it is necessary to determine the range of differences to be expected under any given laboratory procedure between series supposedly identical as to origin, composition and treatment. Several experiments have been run in the attempt to determine the nature and extent of these differences. Figure 7 presents partially the results of one such experiment. These diagrams should be considered, not as curves in the proper sense, but as schematic presentations of certain features of the data. Diagrams of the frequency distribution of supplementaries by groups in each series for a particular week (Fig. 5B) show the relative similarity of these series, whereas similar diagrams for series from different colonies (Fig. 5A) show heterogeneous distributions.

There remain to be worked out effective and justifiable methods of handling data such as these so as to discriminate between differences in expressed reproductivity which result from fluctuating, usually minor variations in constitution and treatment on the one hand, and those differences, on the other, which are significant with regard to the factor under investigation.

SUMMARY AS TO DETERMINATION OF CASTES AND NEOTENIC REPRODUCTIVES IN TERMITES

1. There exists no valid evidence for an intrinsic determination of castes. This would involve genetic segregation, each egg or nymph being predetermined to give rise to an individual of one particular caste.

2. The trend of the evidence and of opinion is in favor of an extrinsic determination of castes. Each egg and young nymph presumably possesses the complete genetic pattern for caste characteristics and is capable, up to a certain point in its development, of giving rise to an individual of any one of the terminal types characteristic of the species, primary reproductive, soldier, worker (if any), or neotenic (supplementary) reproductive. Which of these paths the individual follows is supposedly determined by the external influences to which it is subjected during development.

3. Intercastes such as wing-padded soldiers, and the various soldier-nymphal-neotenic or alate-soldier-nymphal-neotenic intergrades indicate that several of these influences may affect the terminal characteristics of a single individual.

4. No satisfactory evidence has been presented to indicate that differences in diet are among the influences which determine the direction of development of the nymph, whereas there is evidence which makes doubtful the efficacy of food in this regard.

5. There is strong evidence for a direct inhibit-

ing action of soldiers on the production of soldiers, and of functioning reproductives on the production of neotenics.

6. No valid evidence remains for an ectohormonal control, although the existence of such a control is not disproven.

7. The tendency toward neoteny (here termed reproductivity) varies with the instar.

8. Different colonies exhibit the tendency toward neoteny in different degrees.

9. Series taken from the same colony at different times of the year show differences in the rate and extent of development of supplementaries.

10. Laboratory groups decline in population relatively rapidly, presumably in part because of cannibalism and disease, and in part because of unfavorable effects of laboratory conditions and treatment. Wide range in mortality and in reproductivity in groups of the same origin, constitution, and treatment indicates the existence of numerous, only partially recognized variables, control of which should be sought and whose influence on results should be analyzed.

11. In some individual groups there is clearly a negative correlation between mortality and reproductivity; in others no correlation is evident. Statistically no such correlation can be shown for series, especially when correction is made for supplementaries known to have died.

12. The general lack of correlation between viability and reproductivity may be due to the fact that expressed reproductivity is essentially a group phenomenon.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the values of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore, Maryland, U. S. A.*

MAKE MEASURABLE WHAT CANNOT YET BE MEASURED

Being a review of *On Growth and Form* (A New Edition), by D'Arcy Wentworth Thompson. *Cambridge* (The University Press); *New York* (The Macmillan Company), 1942. Pp. 1116. 8½ x 5½ inches. $12.50. *By Edmund W. Sinnott, Yale University.*

The publication of a new edition of D'Arcy Thompson's memorable volume has been eagerly awaited by that host of biologists who have found in *Growth and Form* a treasury of ideas pertinent to almost every field of their science. In the quarter of a century which has passed since its first appearance, this book has kept its place on that small shelf of volumes which must be close to the hand of every investigator who concerns himself with the fundamental problem of organic form. Its influence has been great. Needham calls it "outstanding" and "classical"; Wilson, "remarkable"; Russell, "that admirable book". Julian Huxley expresses his obligation "first and foremost" to it. Indeed, whoever in recent years has dealt with the dynamic aspects of morphology must often have gone to the familiar red volume for suggestion and inspiration. The fantastic prices demanded for second-hand copies during the years when it has been out of print are proof enough of the value which its friends have attached to it.

The reasons for this popularity are not difficult to understand. It was the first persistent attempt to analyze organic form in quantitative terms and to interpret the phenomena of morphology in the light of the simpler facts of mathematics and the physical sciences. Such a program seemed, and still seems, impractical and even theoretically unsound to many orthodox descriptive morphologists, but it gained enthusiastic support from those who saw organic form as something dynamic rather than static and who were eager to apply to morphology those methods of quantitative analysis which had proven so fruitful in physiology and the physical sciences. For all such the appearance of the long promised new edition is an important biological event.

Growth and Form was written in the first World War and rewritten during the second one, yielding its author "solace and occupation when service was debarred me by my years". It is no unimportant service, however, that Thompson has rendered all of us, and the appearance of such a substantial volume at a time like the present is surely a tribute to the serene and imperturbable spirit of its author and to the courage of his publishers.

The new edition is greatly increased in size as compared with the first one—1116 pages instead of 793—but this is almost entirely by accretion rather than reorganization. The book is an example of those organic structures discussed by its author which may show substantial growth with no essential change of form. All the old chapters are here and there are no new ones, and the whole thus continues to resemble a collection of essays rather than a well integrated presentation, and tends to suffer accordingly. Nearly all the original text is still preserved, and at only a few points has it been rewritten. Sometimes there are several new pages together but more often new paragraphs or sentences are interlarded here and there throughout the whole volume so that no subject lacks some added facts, no argument some new and pertinent discussion. It need hardly be said that the same mellow and cultivated style which distinguished the pages of the first edition is found in those of the second. There are 146 new illustrations, most of them excellent, and many of the older ones have been redrawn. The index, unfortunately, is extremely poor. The book is well printed and put together, and a credit to its American manufacture.

In selecting new material from the wealth at his disposal the author has displayed his usual sound judgment and critical acumen. It should be said at once, however, that readers will look in vain for a discussion of

certain topics which they may have expected the author would now include, and for references to many important publications of recent years. Many of the new data are drawn from earlier sources. But to satisfy everyone is obviously out of the question and would require a volume far larger than the limits of the present one.

The author takes occasion, particularly in the introductory chapter, to offer new and vigorous defense of his original purpose "to correlate with mathematical statement and physical law certain of the simpler outward phenomena of organic growth and structure or form" (p. 14). "Numerical precision", he says, "is the very soul of science, and its attainment affords the best, perhaps the only criterion of the truth of theories and the correctness of experiments" (p. 2). The morphologist must be a student of physical science, for "he may learn from that comprehensive science, as the physiologists have not failed to do, the point of view from which her problems are approached, the quantitative methods by which they are attacked, and the wholesome restraints under which all her work is done" (p. 10). And again, much later in the book (p. 1026), "Morphology is but a portion of that wider Science of Form which deals with the forms assumed by matter under all aspects and conditions, and, in a still wider sense, with forms which are theoretically imaginable". There are fewer morphologists today who need to be convinced of the importance of quantitative methods in their science than there were when this book was first written, but the author recognizes that "the introduction of mathematical concepts into natural science has seemed to many men no mere stumbling block but a very parting of the ways" (p. 11). If there are any such, let us hope that they may be numbered among Thompson's readers, for it is his achievement more than that of any other man to have shown how the study of organic form may be raised to a level where it can profitably use the tools of the mathematician and the physicist. He recognizes the wider implications of such a program, however, and states his philosophical position more clearly than before. "The philosopher", he says, "neither minimizes nor unduly magnifies the mechanical aspect of the Cosmos; nor need the naturalist either exaggerate or belittle the mechanical phenomena which are profoundly associated with Life and inseparable from our understanding of Growth and Form" (p. 7). He warns once more against the easy and obvious mechanistic philosophy which attracts so many of his tougher-minded colleagues. The body indeed is a natural and mechanical configuration, but "one does not come by studying living things for a lifetime to suppose that physics and chemistry can account for them all" (p. 14). To this simple statement his amplified discussion of mechanism and teleology adds little. Nor do the great changes in physico-mathematical concepts of the last twenty-five years disturb his conclusions. He dismisses these briefly as of small biological importance since they have little application to bodies of the order of magnitude of living things.

The chapter on Magnitude has received a number of additions, notably with regard to Bergmann's Law, dealing with the relation between environmental temperature and body size in warm-blooded animals; the importance of absolute size for problems of flight; the rôle of very minute bodies in the production or reception of sound and color, and the problem of molecular magnitudes and monolayers. In his discussion of the changed ratio of surface to volume which bears so closely on the determination of absolute size, the author might profitably have mentioned the stimulating studies of his distinguished countryman F. O. Bower on size and form in plants, where many illustrations of this principle are described. The importance of a constant surface-volume relation in determining the size of cells, particularly at division, is somewhat overstressed, since it has been shown that the size of cells in the same tissue may vary widely, even at the time of division. Evidently many other factors than absolute cell size determine the onset of mitosis. It might have been profitable to discuss a little more fully the now extensive literature on cell size which has appeared since the first edition, notably the series of papers by Wermel. In an interesting final paragraph the author contrasts the three scales of biological magnitude—those of man, of insects, and of microorganisms—and shows once again how radically different may be the conditions imposed on organisms simply by their size.

The long chapter on Growth is more thoroughly altered than any of the others. One hundred pages have been added here and the size of the chapter doubled. Many will find the author's treatment of this important topic rather confusing and unclear and will wish that he might have put it all in the melting pot for a complete reorganization. Still under the influence of Quetelet, he introduces the subject by a long discussion of growth in man—certainly difficult and unfavorable material—and only at the end of this portion does he for the first time present a few of those simple sigmoid growth curves which most students of the subject would look for at the beginning. This is continued forty pages later with more material, much of it new, from other organisms. Between these, however, is now intercalated a long biometrical discussion on variability, the curve of error, and the statistics of population growth, much of it mathematical and based in considerable measure on the studies of Raymond Pearl. It is designed to show the similarities between the growth of a population and of an organism. One may doubt whether this comparison is of sufficient importance to warrant such a long digression and many would prefer to leave most of it to treatises in biometry. It is somewhat confusing, incidentally, to find the sigmoid curve discussed for still another time, much later, under

catalytic action, where Robertson's theory now finds adequate treatment.

The author seems little impressed with the compound-interest growth which so many organisms manifest, and although its mathematical statement and Blackman's discussion thereof are mentioned (they were omitted in the first edition) the subject is not given space enough to satisfy most students of growth. Still more remarkable is the brief space (five pages) accorded the important subject of heterogony which has proven such a fertile field of investigation for students of organic form and which, in its discussion at the hands of Julian Huxley, stems chiefly from *Growth and Form* itself.

The effects on growth of various physical factors in the environment, notably temperature, light and water, are considered much more fully than before, but the field is now so vast that any such treatment as this can do no more than cite a few examples. Chemical factors are still more briefly treated. The huge subject of phytohormones, which have proven to be so important in problems of plant growth and development, is discussed but only in a brief paragraph. Animal hormones fare better than before but they occupy only four pages. Vitamins and their significance for growth are not mentioned. The rôle of genetic factors in the control of growth and thus of ultimate size, about which a substantial amount is now known, is barely touched. It is a bit disconcerting to find the summary of this much altered chapter quite unchanged.

New material on the internal structure of the cell is concerned chiefly with the physics of mitosis, to which several pages are added. The author has a little more to say about chromosomes than he had before, but the vital subject of the physical basis of hereditary differences, which has grown up largely in the last twenty-five years, is but briefly touched upon.

"The efforts to explain 'heredity' by the help of 'genes' and chromosomes," says Thompson, "which have grown up in the hands of Morgan and others since this book was written, stand by themselves in a category which is all their own and constitutes a science which is justified of itself. To weigh or criticize these explanations would be outside my purpose, even were I fitted to attempt the task. . . . And I leave this great subject on one side not because I doubt for a moment the facts nor dispute the hypotheses nor decry the importance of one or other; but because we are so much in the dark as to the mysterious field of force in which the chromosomes lie, far from the visible horizon of physical science, that the matter lies (for the present) beyond the range of problems which this book professes to discuss, and the trend of reasoning which it endeavours to maintain" (p. 340).

The students of developmental genetics will be much disappointed that the author should not devote at least a few pages to a subject which they feel is a central one for all problems of organic development.

In the chapter on cell form Thompson has added a single but important paragraph to his brief discussion of the physical structure of protoplasm. The progress which has been made in this field and its great importance for cellular behavior would seem to warrant a little more detailed consideration. The whole problem of surface forces, liquid films, and their significance for cell form, a field which the author has made so peculiarly his own, is further amplified and many beautiful new examples are described. But a note of caution now appears at several points, directed toward those enthusiasts who might attempt to explain all the phenomena of cell form in these simple physical terms. Thus, "we acknowledge and confess that, in simplifying the surface phenomena of the cell, for the time being and for our purely morphological ends, we may be losing sight, or making abstractions, of some of its most specific physical and physiological characteristics" (p. 362). "It would be overbold to seek for every form of living cell a parallel configuration due to simple capillary forces, as manifested in drop or bubble or jet" (p. 434). The author also now draws the significant distinction between a physiological equilibrium and a merely static physical one. "The living cell is seldom in equilibrium. It is continually using or expending energy; and this ceaseless flow of energy gives rise to a 'steady state', taking the place of and simulating equilibrium" (p. 376). Botanists are gratified to find a more adequate discussion of cellulose and its structure, for so many of the problems of plant development are concerned with changes in the cell wall.

In his two famous chapters on the forms of tissues or cell-aggregates, the familiar geometrical figures are still to be found, and the same well-knit arguments for the importance of the principles of minimal area and surface tension in explaining the configurations of cells where they are in contact with each other in masses. There are some new geometric analyses but most of the additions consist of further examples drawn from objects as widely different as insects' wings, basalt columns, smoke patterns, the lining of blood vessels, cycad cones, drying mud and varnish, tortoise carapaces, snow crystals, crackled porcelain, pollen grains and the tests of Peridineae. This subject evidently lies close to the author's heart, and he offers no new caution here against a very general application of these principles in plant and animal tissues. Certainly the ideas of Plateau and Errera, of Lamarle and Lord Kelvin, so persuasively set forth by Thompson, have had a powerful influence in developing a dynamic interpretation of many facts of histology, but we should not allow the elegance of his geometry or the wealth of his illustrations to make us forget the many cases where these principles do not explain all the facts. There are many such. A new partition wall, for example, may be laid down in a position diametrically opposite to that which the law of minimal area requires, notably in the very long and narrow cells of the vascular cambium in plants, which

divide *lengthwise* instead of transversely. In certain tissues, four walls (rather than three) regularly *do* meet at a point despite Thompson's hesitation to admit the fact. Many other cases could be cited where new walls arise in positions far from those which would be dictated by molecular equilibrium. Surface tenson is certainly one of the factors determining intercellular relationships, but there are many others, and the cell surface is more than a simple liquid system.

Kelvin's tetrakaidecahedron and its analysis at the hands of Lewis and Marvin, with their models of actual plant cells, receives much attention. It is unfortunate that the important studies of Matzke, under whom Marvin did his work, are mentioned only in a footnote with the author's name badly mispelled. Topological analysis, which may hold much promise for students of form, receives more space than in the first edition.

The author's treatment of spicules and similar structures is embellished by a number of beautiful new examples from the Radiolarians. He also appends a discussion of Euler's Law concerning polyhedra which shows (among other things) that the character of the facets is limited to a narrow range of possibilities. No system of hexagons, for example, can enclose space, a fact which has important implications for morphology. The forms of living things are by no means infinitely various. Thompson's quotation from Lucretius—"There are things which are possible and things which are impossible even to Nature itself" (p. 740)—might almost be taken as the text around which the book has been written.

The analysis of the logarithmic spiral (now called "equiangular") has received few additions but the material is rearranged rather thoroughly and in a more logical fashion. Some new examples are considered and the development and inheritance of reversal of coiling in snails is treated at much greater length than before.

The chapter on horns and teeth, in the first edition limited almost entirely to the former organs, now has twelve additional pages on teeth of various sorts.

In considering the form and branching of blood vessels the author has considerably expanded his discussion of the principle of "minimal work", that "the cost of operating a physiological system is a minimum", surely a significant idea in any theory of adaptation or organization. One is glad to see that the important studies of C. D. Murray in this field have not been overlooked. The problem of the relation of form to mechanical efficiency gives Thompson an opportunity to add half a dozen interesting pages on the physics of flight in birds, and a number of others on bone mechanics, and for an explanation in dynamic terms of the success of the "American seat" introduced by the famous Tod Sloan, in which the jockey crouches over his horse's neck.

The author amplifies his plea to morphologists not to look upon their subject simply from its hereditary and phylogenetic aspects but to consider other guiding principles. "It would seem to me", he says, "that the mechanical principles and phenomena which we have dealt with in this chapter are of no small importance to the morphologist, all the more when he is inclined to direct his study of the skeleton exclusively to the problem of phylogeny". "To look on the hereditary or evolutionary factor as *the guiding principle* in morphology is to give to that science a one-sided and fallacious simplicity" (p. 1022).

Growth and Form is best known, undoubtedly, for those remarkable transformations of organic forms which its author has produced by the deformation of systems of coordinates. The familiar diagrams are all here, from cannon bone to carapace and from sun-fish to gorilla. There are two or three new ones, chiefly from plants. The author defends the coordinate diagram because it emphasizes "the integral solidarity of the organism, and enables us to see how simple a certain kind of *correlation* is which had been apt to seem a subtle and complex thing" (p. 1037), in contrast to the method of the morphologist—and the geneticist—of picking out and comparing characters which often are only artificial abstractions. There is a short added section on "pattern", by which term, though he does not define it, the author presumably means those aspects of form other than external outline alone. The distinction between "form" and "pattern" seems a difficult and fruitless one to draw.

The two pages of "Conclusion" with which the chapter now ends deserve careful reading by all evolutionists. Useful as the method of transformation proves to be in showing how one type can be derived from another related one, it cannot be employed to trace the entire evolutionary series.

"We *cannot* transform an invertebrate into a vertebrate, nor a coelenterate into a worm, by any simple and legitimate deformation, nor by anything short of reduction to elementary principles. A 'principle of discontinuity,' then, is inherent in all our classifications, whether mathematical, physical or biological; and the infinitude of possible forms, always limited, may be further reduced and discontinuity further revealed by imposing conditions—as, for example, that our parameters must be whole numbers, or proceed by *quanta*, as the physicists say. The lines of the spectrum, the six families of crystals, Dalton's atomic law, the chemical elements themselves, all illustrate this principle of discontinuity. In short, nature proceeds *from one type to another* among organic as well as inorganic forms; and these types vary according to their own parameters, and are defined by physico-mathematical conditions of possibility. In natural history Cuvier's 'types' may not be perfectly chosen nor numerous enough, but *types* they are; and to seek for stepping-stones across the gaps between is to seek in vain, for ever" (p. 1094).

Thus emerge again, in modern terms, the ancient and long outmoded concepts of idealistic morphology so cherished by the founders of the science. May not this principle of discontinuity, suggests Thompson,

explain those gaps in the evolutionary series which seem so difficult to bridge? Must we not look, in tracing evolutionary progress, to large changes, falling along a comparatively few definite lines of physico-mathematical possibility rather than to a host of fortuitous ones leading in every direction? This suggestion seems to the present reviewer the most important new idea in the book. Its bearing on polyphyleticism and orthogenesis, and on the kind of discontinuous evolutionary mechanism proposed by Goldschmidt, is obvious.

Such, then, are the major additions which occupy the 323 new pages of this remarkable volume. They are interesting and important and will enhance the reputation of the author for catholicity of interest and charm of exposition. Nevertheless, most who read it will put the book down with a sense of disappointment, of hopes unfulfilled. The biological progress of the past quarter of a century has been so great, notably in some of the very fields that D'Arcy Thompson has himself illumined, that admirers of the first edition of *Growth and Form* have looked forward to the second in particular anticipation of the clarifying comments on these new morphological ideas which its author would make. These anticipations have been disappointed. One must admit that except for a few places here and there, the revision itself might have been written twenty-five years ago. It is doubtless too much to hope from one author or one book that they should cover this immense field, but his readers could legitimately expect that some of the added pages, instead of being devoted simply to a further elaboration of ideas set forth in the first edition, might have been spent on some of the new facts and theories around which the interest of students of organic form have in recent years so strongly been centered.

Thus, heterogonic growth, a study of which has yielded so much of importance in many fields of both plant and animal development, is given very inadequate treatment. Dimensional heterogony, with its implications for changes of form, is not discussed. Some of the most exciting developments in heterogonic analysis have been in its applications to evolution, notably in the work of Hersh with the fossil titanotheres and of Robb with the horse, but no reference is made to these.

Students of developmental genetics, as we have said, will find no discussion of their subject. The stimulating suggestions of Goldschmidt, Dunn and others as to the relation between genes and the rates of various physiological and developmental processes, by which it is possible to interpret morphological differences of all sorts in simpler terms; the progressive form changes in allelic series; the many genetic analyses of form differences in animals and plants; the problem of heterotic growth—all these are entirely neglected.

The important idea of morphogenetic *fields*, as developed by Weiss, Needham, Waddington and Northrop and Burr, and which is so clearly related to the author's central theme, is ignored. Perhaps more remarkable is the absence of any reference to the idea of "organizers" which has stimulated so much research and speculation by students of development during the past two decades. The related concept of organic gradients, notably the one sponsored by Child, is barely mentioned.

There are of course many other topics which will occur to various readers as worthy of inclusion in such a volume as the present one. Botanists will regret the slender space allotted to polarity, regeneration and meristematic activity in plants, and the absence of reference to those remarkable slime molds studied by Raper in which growth is entirely finished in an amoebal stage and the morphogenetic processes limited to the plasmodial aggregates of these individual cells. Those who have developed the technique of tissue culture, both with plants and with animals, will be sorry that the significance of this work for growth and form is not discussed.

But to ask for all these things is unreasonable and a counsel of perfection. We need not one volume but a shelf of them to cover a field which now spreads over most of biology. *Growth and Form* will minister to this end, for it is a germinative book, a provocative book, and the glory of its author is that he has stimulated other men to attack from many different directions the main objective toward which he has so long been moving. Many years ago he drove forward a strong salient into that terrain, and he now has firmly consolidated his position there. The final assault must come from other workers, many of whom will gain from his example the enthusiasm and devotion necessary for such a task.

BRIEF NOTICES

EVOLUTION

STUDIES ON THE ORIGIN AND EARLY EVOLUTION OF PAIRED FINS AND LIMBS. *Annals of the New York Academy of Sciences, Volume 42, Article 3.*

By William K. Gregory and Henry C. Raven. New York Academy of Sciences, New York. 9¼ x 6¼; 87 + 5 plates; 1941 (paper).

The classical and perennial problem of the origin of the tetrapod limbs and girdles can only be elucidated by painstaking and critical studies of the appendages and girdles of the primitive fossil fishes. The present investigation presents a detailed study of the skeleton of the Devonian crossopterygian, Eusthenopteron, together with a carefully worked out theory concerning the transformation of pectoral and pelvic paddles of the Eusthenopteron type into pentadactylate limbs. The authors also advance a new theory of the origin

of the tetrapod pelvis which provides a reasonable explanation of the triradite suture of the pelvis.

The first part of the paper, which may be considered separately, is a general discussion of the paired fins and girdles of ostracoderms, placoderms and other primitive fishes in which the authors attempt to show that the covering plates of the pectoral girdle of true fishes are derived from the thoracic armor of the ostracoderms and the endoskeletal portion of the shoulder girdle of fishes is an ingrowth from the basal pieces of the pectoral fins. All pertinent literature dealing with these matters is critically reviewed.

An important contribution toward the solution of one of the most puzzling problems of comparative anatomy.

GENERAL BIOLOGY

THE CONSERVATION OF NATIONAL RESOURCES. *An Educational Approach to the Problem.*

By George T. Renner. John Wiley and Sons, New York; Chapman and Hall, London. $2.75. 9 x 6; xi 228; 1942.

As indicated in the preface, this volume (1) "reviews . . . the evidences of resource destruction over the United States, analyzes the fundamental process of resource use, and examines the nature, scope, and development of the conservation idea . . ." (2) "presents in synoptic fashion a résumé of the major problems in our use of each of the principal classes of resources, together with proposed remedial treatments . . ." (3) "seeks to sort and evaluate the materials and information available to the teacher and pupil."

To have covered the field of conservation in this country in any detail would have required many more pages than are included here. Consequently most of the topics are only briefly mentioned. The writer, however, uses many figures that one would like the original source of, such as "House cats are reputed to kill between 15,000,000 and 20,000,000 birds each year in the two states of Iowa and Missouri alone." There are also a few misstatements concerning the extinction of bison and elk, and one that claims that parakeets are "almost" gone. Of more serious import is the explanation of inheritance that the writer unfortunately includes in his discussion of human resources. It would have been better had this section been omitted. On the whole, however, for a broad panorama of conservation in this country, the book will provide a handy reference.

OUT OF DOORS IN SPRING.

By C. J. Hylander. Illustrations by the Author. The Macmillan Company, New York. $1.50. 8 x 6; 143; 1942.

This small volume is the first of a series of four—one for each season—written especially for young people to show them what birds and flowers to look for at the various times of the year and to help them enjoy the out-of-doors from season to season.

The keynote of this "Spring" volume is the usual one—nature's reawakening after a long period of lessened activity. The awakening of the trees, the stir of life in the ponds, the beginning of the "flower parade" and the return of the song birds, all go to make spring time the most exciting, perhaps, of all the seasons. In seven chapters we are told how and where to search for the first signs of life among the wild plants and animals. In these explorations the author takes his readers through wet woods and reedy swamps, around the edges of fresh-water ponds, up through thickets and wood land, across ravines and grassy meadows, taking pains always to point out the characteristic plant and animal communities. While the book as a whole is relatively interesting and informative, there is nothing particularly original or new in the way the facts are presented.

HUMAN BIOLOGY

NEGROES IN BRAZIL. *A Study of Race Contact at Bahia.*

By Donald Pierson. University of Chicago Press, Chicago. $4.50. 7⅞ x 5¼; xxi + 392; 1942.

This is a book that should be read carefully by everyone interested in racial problems. In Brazil, the three components of the population—whites from Europe, Blacks from Africa and native Indians—are approximately equal in number. Such a situation ought to be frought with greater danger than that of our own country, where the Negroes and the Japanese constitute significant minorities, yet there is no race problem at all in Brazil. And an educated Brazilian told the author "We Brazilians are rapidly becoming a single race."

To understand such a situation it must be remembered that for five centuries Portugal was dominated by a dark skinned race—the Moors. The native inhabitants of the Iberian peninsula were a light skinned people, due to the influx of Goths and Vandals, blond peoples of Teutonic affinities. Their culture was not high—the name Vandal has become a byword for an enemy of culture. In contrast, the Moors were the most highly cultured people in Europe.

The Moors, of course, are not a negroid people. But the Berbers who accompanied them were no longer of pure stock, being to a large extent diluted with Negro blood. Under Moorish domination the Berbers and native Portuguese enjoyed the same social status, with the result that when Brazil was discovered there was already a large admixture of Negro blood among the lower class Portuguese. At this time Portugal controlled the largest empire in the world, with colonies in

Africa and the Indian Ocean whose coast line exceeded the equator in length. Yet the population of the mother country was less than a million, and to maintain the empire it was necessary to export about eighty thousand able-bodied men annually. To supply these, the Portuguese women were degraded to the status of breeding machines. None were allowed to leave the country except those who had no propagative value. The result was that the colonists, who had no delusions of grandeur concerning the superiority of the white man took wives from among the native women, and the marriages were sanctioned by both church and state. Of course, some of the colonists already had families in the old country; these could not contract legal marriages but this did not prevent them from raising "brush families" and when they returned to Portugal they frequently brought their black progeny home to be educated along with their white half-siblings, and to share the same homes and social privileges. Meanwhile the father frequently paid an annual income to his companion of the brush. Strange as it seems, the white wife welcomed the black children to her home—perhaps out of gratitude that she didn't have to share it with her husband's dusky concubine as well.

Into such a Brazilian society slavery was introduced. The number of slaves was enormous, over a million a year, and soon the blacks outnumbered the whites and Indians together by about twenty to one. Most of these slaves took the places of older slaves who had been manumitted, for slavery was not considered a permanent condition—sooner or later every slave took his place as a free responsible citizen of Brazil. Every woman was given absolute freedom when she had born ten children, and every man was given one day a week in which he might earn money to buy his freedom for a sum not exceeding $140.00, and frequently less. No slave owner was allowed to withhold freedom from a slave able to purchase it, and every slave holder was expected to provide in his will for the manumission of all his slaves. This last was not compulsory, but as it was considered something of a social disgrace to inherit a slave, it was the usual practice.

It must not be inferred from this that the slaves had an easy time. Far from it. Frequently they were punished at the whipping post for some inconsequential infringement of a minor regulation, but when this was done the owner was responsible to the state for any injury that might be done to the slave. There were also frequent outbursts of violence between the whites and blacks whenever the latter could arm themselves. The whites were generally warned of the impendence of such an event by the slaves themselves, who were always found fighting beside their owners against the free blacks when open hostilities commenced.

The slave holders of the Confederacy would have advanced this as an argument against liberation, claiming that the way to keep a Negro pacified is to keep him in slavery, while the militant abolitionists of the northern states would have claimed that war was the less of two evils. But both would have been wrong. The wars in Brazil were not the outcome of slavery or of race prejudice; they were jehads. The slaves in Brazil were recruited from that part of Africa that was essentially Mohammedan; they were all disciples of the prophet and they increased their number by successful proselytism among those Indians whom the Roman communion had failed to Christianize. The holy wars of the old world ceased about the time of the expulsion of Boabdil, but they continued to be fought on American soil until the importation of Mohammedan slaves had ceased, and they had nothing in common with the armed insurrection of Harper's Ferry.

One more generation will probably see the disappearance of the pure bred black in Brazil. The absorption of the pure black by the mestiçs takes place more rapidly than commonly supposed; there are said to be numerous mestiços in Brazil whose white skins and Nordic features would enable them to "pass" north of the Rio Grande, yet who had one grandparent as black as coal. But when the author attempted to locate one of these he was told "We don't discuss the color of our neighbor's grandparents. We don't think it is polite."

The present reviewer has endeavored to show the difference in the factors that have operated to produce the social structures in the largest countries in the two Americas. The interested reader who desires to pursue the matter further should read the book, which is well written and documented. The footnotes give in English translation the exact information that is needed for an intelligent reading. And it should be read intelligently, for it is not unlikely that Brazil may become the cultural leader of America within the lifetime of people now living.

FOREIGN DEVIL. *An American Kim in Modern Asia. By Gordon Enders. Simon and Schuster, New York.* $2.50. 8 x 5¾; 307; 1942.

"While Dewey's dash for Manila Bay was thrilling America . . .", Gordon Ender's father was taking his wife and family to India to establish a mission settlement there beside the Grand Trunk Road of Hindustan. It was there that young Gordon received his first impressions of India as it literally passed by his door.

Jowaru Singh, a high-caste Hindu, was the chief servant in the Enders' mission. He also acted as teacher to young Gordon, and was the first of three Eastern teachers who helped him to understand the East. Jowaru Singh took it upon himself to teach and clarify all matters pertaining to India life. Through him it was that the author really began to understand India, its peoples and customs, and to realize that

the enigma of the East is that there is no enigma. Men and women, there as here, meet as best they can, with the means at hand, the problems of daily living. If their methods strike us often as inadequate, ours as often seem preposterous to them. But below these superficialities, we are alike. East and West are geographical expressions only.

With Jowaru Singh, Enders saw, one summer, the unfinished meal of a man-eating tiger; the river floating full of the victims of floods; the crows feasting on the severed head of a murdered boy; and the burning of corpses. Also that summer Enders saw the Indian Ocean monsoon come, deluging with rain the dried and cracked ground, but arriving too late to revive the exhausted earth and prevent famine. Before the famine came, however, two of the biggest religious festivals were celebrated by the Hindus and Mohammedans. The festivals were more than religious for in them was the hatred of Hindu and Mohammedan for each other. A fast preceded the festivals and fighting ended them, robbing the coming famine of many victims. The Enders' mission at this time played an important rôle in relieving the distress of famine and disease.

The second of the author's eastern teachers was Chanti. He was a graduate of an American mission school, spoke English well but was a genuine Tibetan. His belief that the British could teach the Tibetans much made him a valuable spy for Great Britain in Forbidden Tibet. Trained in the use of thermometers, compasses and secret codes, he brought back data from which were made the first modern maps of Tibet. Chanti believed that Tibet could develop only under Western ideas and that through his pupil Enders or another like him "might be forged the opening wedge which would let the light of modernism in upon the dark corners of Tibet." No opportunity was missed to bring Enders into contact with Chanti's countrymen and through him many ideas for the solutions of Asiatic riddles were suggested. The Tibetan is pictured as gay and high spirited, fond of conversation, gossip and amusement. He is somewhat lazy and stubborn and works slowly, but when aroused can be inhumanly cruel. Enders' visit to the monastery of Rakas in Tibet is very descriptive of the details of food, clothing, housing architecture, and habits of the Priests and Lamas. The story of how the incarnate head of Rakas became a local deity is interesting, as is also his explanations of Buddhism. The visit to the Monastery of the Caves proved exciting as Chanti went to the rescue of a young boy who was about to become buried alive in the ceremony of becoming an abbot.

The third of the eastern teachers of Enders was the man-god Incarnation, the Panchan Lama of Tibet. Breaking all historic precedents, Enders was appointed to the Upper House of the Tibetan National Assembly to serve as technical adviser of aviation. This appointment gave him rank in the Tibetan nobility, the title of General, and membership in the Incarnation cabinet. He could approach the Incarnation at any time or place and speak to him on any subject, a privilege other cabinet members did not have.

The reader may be surprised to know that, in the dark and Forbidden Kingdom of Tibet, the Incarnation was entirely familiar with every detail of all the modern inventions of the West. Radio, airplanes, motion pictures, engineering, surveying, medicine, and dentistry. It was his untiring life-time work to make his people happier and to make the use of these inventions accessible to his own followers. Airplanes were the first of these desired and resulted in Enders' appointment as aviation adviser. The gold in Tibet was to be flown over hundreds of miles of robber-infested back country to exchange for power plants, road-making machinery, motor cars, radios, etc. It is of interest to note that today China is receiving thousands of ounces of gold from Tibet.

Through contact and friendship with the Panchan Lama, Enders came to know Tibet in no other way possible. Jowaru and Chanti had fitted him well for this task. "Chanti's dream of a new Tibet was beginning to take shape."

BIOLOGICAL SYMPOSIA, *Volume VIII. Levels of Integration in Biological and Social Systems. Series Edited by Jaques Cattell. Volume VIII edited by Robert Redfield. Jaques Cattell Press, Lancaster, Pennsylvania.* $2.50. 9⅜ x 6⅛; 240; 1942.

This is a collection of eleven papers which had been presented as a symposium at the celebration of the fiftieth anniversary of the University of Chicago. It is the new, useful, and stimulating result of bringing together biologists, anthropologists and sociologists interested in social integration and, ultimately, the evolution of societies. In general these papers are arranged in an order corresponding to the increasing complexity of the organisms dealt with, but the chief aim has been to reveal the developmental sequence of levels of integration.

The introduction of 26 pages by the editor shows the underlying unity of these eleven diverse essays and represents an excellent summary of the complicated group of facts and problems which formed the focus for the symposium.

The first paper of the series is by L. H. Hyman and deals with "The transition from the unicellular to the multicellular individual." Here the reader is introduced to evolutionary events among the lowest animals, for which are given convincing, though hypothetical, explanations. The second paper, by J. W. Buchanan, bears the title: "Intermediate levels of organismic integration." This report concerns itself

with physiological conditions in flatworms and annelids and shows the laws whereby parts of an organism are subordinated to the whole. The third contribution is by R. W. Gerard who discusses "Higher levels of integration," reviews phylogenetic trends in transmissive mechanisms, and compares the formation of an organism out of its component parts with the origin of society out of individuals. This is followed by a paper on "Synergistic aspects of bacterial populations" by W. Burrows. This author lists the effects of association between specifically different bacteria in producing conditions impossible to achieve by either unmixed population. The fifth paper of the series is by H. S. Jennings, who writes on "The transition from the individual to the social level." Based upon his lifelong investigations this writer analyzes social interactions and the nature of society in protozoan aggregations. The next chapter, by T. Park, takes up: "Integration in infra-social insect populations." Here it is shown that influences from a genetic or an environmental source, or "pressures", "are integrated in the sense that, as in an organism, change in one affects another and always results in some compensatory regulation in the system."

Vertebrates are first discussed in this symposium in the seventh paper, by W. C. Allee, who writes on "Social dominance and subordination among vertebrates," considering chiefly fowl and mice. The first explicit and comprehensive comparison between subhuman and human societies is found in the following paper by A. E. Emerson: "Basic comparisons of human and insect societies." Here are presented the general factors which have led to the formation of societies at two widely differing organic levels, stressing the adaptive character of increasing integration.

In the ninth paper of the series C. R. Carpenter reports on his many and pioneering findings regarding: "Societies of monkeys and apes." He deals with the relation between sex- and age-groups, with intergroup and interspecific relations and with the relations of the "clan" to its environment, all of which factors can differ very significantly with species or genus. A large rôle in producing integration in societies of non-human primates falls to sign-mechanisms, especially vocalized symbols.

The last two contributions are devoted to an analysis of human societies. A. L. Kroeber writes on: "The societies of primitive man" and R. E. Park on "Modern society." The former paper outlines the main features of that highly developed mechanism of conventionalized symbolic behavior which is peculiar to man. The last study emphasizes the significant differences in levels of integration within man's organized social systems and discusses the interrelation of technological, economic and political factors in modern human society.

This scholarly and much-needed book demonstrates clearly that human society can and does change far more rapidly than any animal society. To some readers the technical language of these essays will not always be fully intelligible, particularly since some terms are not used in a consistent manner by all the contributors.

CRIMINOLOGY. *An Attempt at a Synthetic Interpretation with a Cultural Emphasis.* *By Donald R. Taft. The Macmillan Company, New York.* $4.50. 9¼ x 6; xii + 708; 1942.

This is a book that demands serious consideration. The author, Professor of Sociology at the University of Illinois, has gathered together within the pages all of the significant knowledge concerning crime and gives a keen analysis of the factors that are influential in the production of criminals. The discussion is confined almost entirely to crime and its treatment in the United States. He points out that there is need for the same thing to be done for other countries, particularly for the penal system of Russia, although that system is now undergoing fundamental changes.

Taft's thesis is that criminals are products. Admitting that this stand is open to criticism, nevertheless, he maintains, that

"If there be a justification for assuming such *a deterministic position*, it is that the assumption most nearly fits the facts thus far observed both in criminology and in the "sciences" upon which criminology is dependent. Once the assumption is granted there follows a very different and more hopeful attack upon the crime problem than has been usual outside of a few textbooks and research volumes."

Inheritance is not disregarded, but he believes that the "personalities which function and which may commit crimes are always compounds of a subjective heredity and an objective experience" . . . "that whatever hereditary factors significant for crime may be, they are always relative to social situations—to social experience." He considers the well-known cases of so-called degenerate families, Goring's statistical studies of criminals in families, and other works on twins and criminals. A satisfactory interpretation of such studies is difficult in that the part which environment has played in these cases has not been sufficiently appraised. Taft's tentative conclusion is "that there presumably exist heredity factors significant, in some cultures and under certain types of social situations, for criminal behavior . . ." but that "none of these genetic factors predestine the individual to crime independent of experience."

In his discussion of the excessive criminality among Negroes, Taft points out the many handicaps under which the Negro labors. "Nearly every condition that is considered a handicap to successful social adjustment is far more prevalent among Negroes than among whites." Concerning crime among immigrants,

he finds that a good deal of study is yet to be done concerning the adverse conditions under which the different nationalities live and the "nature of the culture which they bring with them" before it can be said that certain groups are more criminal than others. The high delinquency rates among the children of immigrants newly arrived can undoubtedly be traced to the difficulties of adjusting themselves in the new environment. In a section on economic conditions and crime Taft emphasizes the effect of economic competition rather than the lack of economic necessities as being conducive to crime. "If the analyses of socialists have at times overstressed the importance of the capitalistic system generally nevertheless the competitive nature of the economic system is clearly an extremely important source of delinquent patterns.

Other sections, in that part of the book which has to do with the explanation of crime, are on the influence of the family, crime distribution, companionship and the juvenile gang, organized crime, influence of newspapers and religion, sex delinquency, crime as a product of American culture, and alcohol and drug addiction.

Fourteen chapters deal with the treatment of the adult criminal. Here Taft surveys the subject from all angles. He gives a most interesting section on the effect of the prison community as experienced by the convict. There are also several chapters devoted to the treatment of the juvenile delinquent and crime prevention.

Taft writes with great clarity and precision. While the volume will probably find it greatest usefulness as a text for graduate students, in the reviewer's opinion, it could profitably be used in courses in adult education. The volume is completely documented with footnotes, and for nearly all of the 40 chapters there are references lists. Indexes of names and subjects are provided.

FAMILY EXPENDITURES FOR PERSONAL CARE, GIFTS, SELECTED TAXES, AND MISCELLANEOUS ITEMS: *Five Regions. U. S. Department of Agriculture Miscellaneous Publication No. 455. Consumer Purchases Study. Urban, Village, and Farm Series.*

By Day Monroe, Dorothy S. Brady, Edith Dyer Rainboth, and Ellen D. Riley. Government Printing Office, Washington, D. C. 20 cents. 9⅛ x 5¾; iii + 113; 1941 (paper).

FAMILY INCOME AND EXPENDITURES: *Southeast Region, Part I. Family Income. U. S. Department of Agriculture Miscellaneous Publication No. 462. Consumer Purchases Study. Farm Series.*

By Dorothy S. Brady, Day Monroe, Margaret Perry, and Mary Ruth Pratt. Government Printing Office, Washington, D. C. 25 cents. 9⅛ x 5¾; vi + 208; 1941 (paper).

FAMILY INCOME AND EXPENDITURES: *Five Regions. Part 2. Family Expenditures. U. S. Department of Agriculture Miscellaneous Publication No. 465. Consumer Purchases Study. Farm Series.*

By Day Monroe, Dorothy S. Brady, Margaret Perry, Kathryn Cronister and Edith Dyer Rainboth. Government Printing Office, Washington, D. C. 35 cents. 9⅛ x 5¾; v + 366; 1941 (paper).

In Part 1 of the study on *Family Income and Expenditures*, family income was surveyed in four race-tenure groups of farm families—white farm operators, white sharecroppers, Negro farm operators and Negro sharecroppers. Farm operators were defined as "entrepreneurs responsible for the farm enterprise whether they are owners, or cash or share tenants. The sharecropper is defined as the tenant who rents land on shares, is furnished the work stock and in some cases tools and equipment by the operator, and works under supervision."

Four typical sections were surveyed—eastern North Carolina, South Carolina, Georgia and Mississippi. The report includes tenure, age of husband, size and value of operated farms; description of native-born unbroken families and of their household sources of family income; family composition and income; food, housing, fuel and other products furnished the family by the farm.

In Part 2, the survey was made in 64 farm counties in 20 states representing the major types of agricultural production in the country. Only families of white farm operators were studied except in the Southeast where special studies were made of Negro operators and of white and Negro sharecroppers. All families were native-born and had received no help from wellfare agencies during the report year. Reports are given on family consumption in relation to income in the Pennsylvania-Ohio farm section; consumption as related to family composition, Negro farm operators' families, and Negro and white sharecroppers' families in the Southeast region.

Interesting comparisons are made between urban and farm families.

Farm operator families learn to look ahead; they are entrepreneurs, managing a business enterprise which does not operate on a day-to-day basis. Small wonder, therefore, that living within their incomes and setting aside some surplus for building up the farm business seems to be characteristic of farm families. Urban families, on the other hand, are working for others and thus, perhaps, lack an entrepreneur's incentive for saving and learning to manage resources. Of these middle-income farm families in Pennsylvania and Ohio, 70 percent had a surplus or broke even; 30 percent were "in the red" at the year's end. But among the Chicago families with comparable income, 43 percent, an appreciably larger proportion, had a deficit. The farm group as a whole had an average surplus of $26; the metropolitan, an average deficit of $63.

In the report on personal care, gifts, selected taxes and miscellaneous items, the families providing the data were drawn from 20 small cities, 140 villages and 64 counties comprising 13 farm sections.

As usual with these reports a large part of each one is taken up with the collected data, arranged in tables.

SOCIOLOGICAL FOUNDATIONS OF EDUCATION. *A Textbook in Educational Sociology.* *By Joseph S. Roucek and Associates. Thomas Y. Crowell Company, New York.* $3.75. 8⅝ x 5⅜; x + 771. 1942.

This is a symposium by 32 contributors, each of whom considers a different phase of education. That the state of our education system today is not everything that it should be is evidenced by the action of a recent convention of college presidents, at which a resolution was adopted declaring that they had no interest in education as such, but only insofar as it might be a means toward winning the war.

Nothing but disaster could result from the wholesale sacrifice on the altar of Mars of the traditional ideals of American education, and the present reviewer is happy to state that the contributors to this volume have not yielded to the pressure of popular but misinformed opinion. They have presented us with a well reasoned analysis of all the social aspects of education, free from prejudice or propaganda, and except for the single chapter dealing with education for war and peace (which is the only weak point in the work) there is little to indicate that the book was compiled during the most violent war in human history. The several contributors appreciate that while it takes time to fight a war through to a conclusion, any one war is ephemeral as compared in duration with civilization, and after this war is over saner counsel will again prevail and a more rational state of mind be restored. When that happy time arrives the volume under review will be just as timely and as helpful as it is today.

It was stated above that the chapter on war and peace was inferior to the others. It seems somewhat superficial. It makes no mention of the International Institutes held every summer in over a dozen colleges scattered from coast to coast. It says nothing about the splendid example of intercollegiate cooperation afforded by the eastern colleges who have taken over the education of American citizens of Japanese descent from the institutions located within the exclusion area on the coast. Nor does it note the activities of the approximately thirty colleges operated by the historic "peace testimony" churches, or the special instruction into the way of peace offered by Columbia to a limited number of selected Civilian Public Service workers. A recent and more strikingly original venture by Princeton deserves to be watched.

The other chapters are very thorough, penetrating and thought provoking, and make the reader wish to learn more. For instance, consider the statement that there are only three denominational universities west of Chicago. But there are at least seven claiming that classification. Does the author question their denominational control, or their right to university rank?

But there is much more than institutional education covered in this work. Radio, the movie theater, home and family life, the public playground—all these are discussed as well as such related subjects as mental hygiene, grades of mentality, juvenile delinquency, education of immigrants, rural communities, and pedagogical psychology. The book is provided with one of the most complete indices this reviewer has ever seen—it covers twenty-seven pages, and is well worthy to be held up as a model for other writers to imitate.

GUAM AND ITS PEOPLE. *A Study of Culture Change and Colonial Education. Studies of the Pacific, Number 8.* *By Laura Thompson. American Council, Institute of Pacific Relations, New York; in cooperation with the University of Hawaii.* $2.50. 9 x 6; xii + 308; 1941 (paper).

This analysis of the life and social practices of the peoples who inhabit Guam is very timely. This island occupies a very strategic geographic position, lying near the point where the straight line from Honolulu to Manila intersects that from Yokohama to Port Moresby. It is also the largest body of land within the trapezium of which these lines are the diagonals. Its population is derived from four sources: the aboriginal inhabitants, called Chamorros; immigrants from Japan, the Philippines, and the Carolines, whose amalgamation with the aborigines is now so complete that there are no pure-blooded Chamorros left; the Spaniards, a step higher in the social scale; and the Americans, whose personnel is so transient that they have not amalgamated at all and can hardly be considered other than a superimposed caste.

Two different cultures cannot coexist permanently in the same habitat. Either one will disappear before the advance of the other, or the two will fuse to form a third culture. The Mediterranean peoples have inherited from the Roman Empire a tendency to fuse with their conquered subjects, but the Nordics tend to remain Nordics wherever they settle. During several centuries of Spanish occupation the native culture and language flourished, undergoing evolution as the result of contact with the Franciscans, the Jesuits, the Augustinians, and the Capuchins, who controlled the educational system by turns, but in the scant half century of American domination the use of the Chamorro language has been outlawed in the public schools and on the playgrounds, and if present day trends continue it is

not impossible that another generation will see the extinction of indigenous culture.

The present study was completed before the Nipponese took control. Consequently it cannot be used as a basis for prognostication of the future course of events. As a record of social evolution it is invaluable, and it has been made none too soon.

The writer has pretty completely covered the social, economic, hygienic, educational, moral, and religious aspects of her subject. While she draws chiefly from her own observations she is also not unmindful of the numerous other writers who have preceded her, beginning with Sanvitores, the Jesuit who met his martyrdom on the island in the seventeenth century. There is no collected bibliography but bibliographic references are abundant in the footnotes.

To the present reviewer the most interesting item in the book is the all too painfully brief mention of the Guam Institute, a normal school founded by a Filipino surveyor early in the present century. One would like to know its scholastic standing compared with that of the Washington High School. Certainly it must represent a unique experiment in education.

The work is well indexed and illustrated.

CAREERS IN WILDLIFE MANAGEMENT. *Occupational Monograph No. 29 of the American Job Series.* *By Charles N. Elliott. Science Research Associates, Chicago.* Free. 9 x 6; 49; 1942 (paper).

This monograph has been prepared especially to inform those who have a desire to enter the field of wildlife management, or to serve part-time in this work, how a training can be obtained, the history of American wildlife, its importance in war and peace, the jobs of wildlife workers, the wages they earn, the personal qualities they must possess, and the good and bad features about their jobs.

One of the most important fields of wildlife management is in the protection of birds. There are probably more than four billion birds in the United States—including both game and non-game species. While seeds and vegetable matter form the food of some of these, most of them eat insects and many consume several times their weight in insects every day. Without this great consumption of insect life by the birds man would be in a sorry plight as regards his own living. Due to lavish killing in the past many species of birds have become extinct or nearly extinct. The disappearance of the passenger pigeon is a classic example of the lack of law enforcement. It is said that within two years (around 1878) actual records show that 15,840,000 wild pigeons were shipped to market from Shelby, Michigan, and in one year alone, 14,850,000 from Petosky. "The last passenger pigeon the world has ever positively seen died in the Cincinnati Zoological Park in 1914." ". . . The last known great auk was killed in 1844." Another victim of careless destruction was the bison or buffalo. For many years they were killed for their tongues alone, which sold in market for 50 cents apiece, the remainder of the animal being left to rot on the prairie.

Today, with conservation the rule, and serious efforts being made to enforce the laws, many game animals, such as waterfowl, deer, elk, moose, and European wild boar, are on the increase. It is estimated that the migratory waterfowl population has been brought from "an all-time low of 27 millions in 1934 to more than 70 millions at the present time."

About 222,800 persons are now employed in all phases of wildlife work. The largest number, 130,000, are in fisheries, then follow guides, 48,000; trappers and fur farmers, 22,000; Federal workers, 9,340; State workers, 5,960; farmers who own shooting preserves, 6,500; and finally a miscellaneous group of about 1000.

Elliott gives the essential requirements for a wildlife specialist: "A good game management agent should have some of the training, experience, and characteristics of an athlete, a mechanic, a boatman, a biologist and farmer, a public speaker and writer, a detective and policeman, a lawyer and a diplomat." Many colleges and institutions now give courses in wildlife management. Nine cooperative wildlife research units have been established in various parts of the country, in connection with educational institutions, by the Biological Survey, where specialized training in wildlife research and management, leading to advanced degrees, is given. All of these institutions are listed and the work concludes with a brief bibliography.

UNIVERSITY OF COLORADO STUDIES. *Series C. Studies in the Social Sciences. Vol. I, No. 3. A Colorado Editor and His State*, by A. Gayle Waldrop; *The Criminality of the Colored Woman*, by Hans von Hentig; *A Preliminary Report on the Monument Ruins in San Juan County, Utah*, by Leonard L. Leh.

University of Colorado Press, Boulder. $1.00. 10 x 6¾; 207–293; 1942 (paper).

The author of the second paper in this series of studies was formerly Professor of Criminal Law and Criminology in the Universities of Bonn and Kiel. He analyzes the available data on the criminality of colored women using records from many different sources. He also surveys data on sex ratio, mortality rates, admission to state hospitals, illiterates, marital condition, occupation, and victims of homicide (both colored and white), and, for certain categories, includes data on white and Negro males. While the figures show that there is greater criminality among Negro women than among white women, von Hentig points out that this does not mean that the colored women are inherently inclined to

greater delinquency than the white women. Many factors must be taken into consideration in connection with the statistics. Considerable weight must be given to the change of environment which the Negroes in this country experienced when they were brought in as slaves.

The Negro's adjustment to African conditions had probably reached a high degree of perfection, physically, mentally, and socially. The Negro slaves who were imported into the United States had to start anew, not only to adjust themselves to new climatic and social conditions, but to a world which was to them artificial and unreal. Polygamous institutions of their native continent were relieved by two hundred and fifty years of compulsory promiscuous sex relations. Initiative was suppressed, obedience and submission were bred, and since enforced submission always creates a split mentality, certain characteristics were imposed and overemphasized: laziness (which we find in all prisons), improvidence, supersensitiveness, excitability, and other traits which the writer has tried in his former study to explain partly as necessary and useful adjustments to life in the primitive forests and under the climatic conditions of Africa.

Another factor which the author stresses is the higher morbidity and mortality of the Negro. ". . . death is not brought about suddenly, but mostly is the final result of a long pathological process. In the course of the process, the mind is affected as well as the organism. Disease, in its first stages, often changes the character and the moral reactions of man." Consideration must also be given to the type of occupation open to the colored woman and the "conflict-laden atmosphere" of Negro communities.

An interesting analysis is made of arrest figures per 100,000 illiterates (females, white and Negro) for 1936–1938. The data show that by classification under the following headings—homicide, robbery, aggravated assault, burglary, larceny, embezzlement and fraud, prostitution and disorderly conduct—the whites surpassed the Negroes in burglary, embezzlement and fraud, and prostitution, and in larceny and disorderly conduct the whites and Negroes were not far apart.

ORIGIN OF THE FAR EASTERN CIVILIZATIONS: *A Brief Handbook. Smithsonian Institution War Background Studies Number One. Publication 3681.*

By Carl Whiting Bishop. Smithsonian Institution, City of Washington. Free. 9 x 6; 53 + 12 plates; 1942 (paper).

THE EVOLUTION OF NATIONS. *Smithsonian Institution War Background Studies Number Two. Publication 3686.*

By John R. Swanton. Smithsonian Institution, City of Washington. Free. 9 x 6; 23; 1942 (paper).

THE PEOPLES OF THE SOVIET UNION. *Smithsonian Institution War Background Studies Number Three. Publication 3690.*

By Aleš Hrdlička. Smithsonian Institution, City of Washington. Free. 9 x 6; 29; 1942 (paper).

The first of these handbooks gives an interesting and clear account of the peoples, customs, economics and culture of the Far East. The forms of early man in eastern Asia and the later wanderings of Paleolithic man are discussed, along with the cultures of the Neolithic and Bronze Ages. This survey reveals one outstanding fact, that as civilization advanced in the Old World, it developed not one but two great centers of culture diffusion—the Near East on the one hand, China on the other. A list of references and a selected bibliography are given at the end of the handbook. The illustrations, especially the twelve plates, are exceptionally well done.

It is commonly believed that our American Indians were divided into a limited number of distinct tribes which originated and continued to exist in a manner suggestive of the immutable species of the older biologists. The same view is entertained by many regarding nations in general. They are supposed to have come through divine or through natural determination. The second of the above handbooks shows that when we turn to examine the more advanced states or "nations" we find with them, as with the Indian tribes, a total lack of any one unifying principle or set of principles that would lend color to the dogma of an immutability in their number or their constitution. The author reviews the history of the more important of these ancient and modern "nations" to make this evident.

The third handbook gives a brief but authoritative ethnological and anthropological discussion of the Russian people. The book is based on the writer's observations during three study trips to Russia and Siberia, on reliable historical records, and on official data of the Soviet Union. Material discussed includes: the present population of the U. S. S. R., the peopling of Russia, movements of peoples in European Russia, the western and northwestern nations, peoples of the Caucasus, and the principal and the smaller Asiatic peoples of the Soviet Union. The languages and physical standards of the people are also described.

PANGOAN DIARY.

By Ruth Harkness. Creative Age Press, New York. $2.50. 8 x 6¾; 295; 1942.

The word "Panda" will quickly recall to the reader the name of the woman explorer and author, Mrs. Ruth Harkness, who several years ago discovered in the China-Tibet border the first baby giant panda and brought this rare animal back to the United States. She has written two books about her adventures in search of the panda. In this, her third book, Mrs. Harkness writes of her search for another rare animal, a silver-gray bear, the species of which had once existed but of which only slight information was now available.

While traveling to Lima, Peru, for a rest and a change, Mrs. Harkness is soon persuaded by friends to look for this rare silver-gray bear, the search for which takes her in and around the remote Andes of South America and among unfamiliar and strange people. It is of this distant and primitive region that the author writes, relating her experiences and those told to her by her native guide and friend Sandoval. She writes of savages who kill the parents of entire villages, kidnap all the children to later sell them as slaves; of Sandoval who loved children and had rescued several; of a family of German colonists, strange to be found in this remote country; of Christmas in the jungle; of the hardship of finding food; of black magic; of vampire bats and their mysterious disappearance; and of forest dwellers whose costumes consist of a single loose garment, the only notable item of civilization accepted in over four hundred years.

It is interesting to note how primitive many of the native Indians of Peru described in this book are. The Salvajes, for example, the uncivilized dwellers of the forests, have their faces painted bright red and use the bow and arrow for weapons. Many pure Indian of the coastal region of Peru is often mistaken for Chinese.

A brief review of the past history of Peru and of how the Indians were mistreated by the Spaniards four hundred years ago gives reason enough for the silent and secret way in which the Peruvians guard their land. The rich treasures of gold and silver now probably hidden in caves and under rocks of the high Sierras, together with many ancient hidden mines worked long before the Spaniards came, will some day come to light ". . . when the white man and his greed for gold are gone".

The book is written from a purely descriptive, rather than an anthropological, point of view.

AMERICAN NEGROES: *A Handbook.*
By Edwin R. Embree. The John Day Co., New York. $1.00. 7⅞ x 5; 78; 1942.

To those who are acquainted with the author's *Brown America* this volume has little to offer since it is made up largely from the same material. However, during the present general reorientation of the attitudes of the American people towards minority groups it is well to have this compact volume at hand. To those who have never made a serious study of the progress which the American Negro has made since slave days the volume has much to offer and to such individuals we recommend it as important reading. One wishes that the accompanying bibliography could have been extended to include more of the fact-finding works of competent students.

It is important that American whites should thoroughly comprehend the biological make-up of the American Negro. The slaves were drawn from large parts of Central and Western Africa, from tribes of wholly different physical constitutions, mental attitudes, and customs. They were "Moors from the northerly coasts, the small yellow Hottentots from the south, Bantu tribesmen from the equatorial regions, the peoples of the Cameroons, the Congo, and the vast stretches of the Niger Valley, the large blacks from the region about the Gold Coast." Many of these tribes were far from barbarism. Of these captured slaves only the best in physique and courage survived the terrible ordeal of transportation. In this country the process of intermingling of all these various extractions from Africa with whites and Indians brought into existence a wholly new race which is distinctive in itself. It is estimated by Herskovits "that not over 20 per cent of people classed as Negroes in the United States are of purely African parentage." While there was this great intermingling of the various strains of Africans, whites of European extraction, and American Indians in the early days (the greatest amount of interbreeding occurred a century ago), since emancipation sentiment among both whites and blacks has been against it. Recent studies show that "American Negroes are forming a group astonishingly uniform in its physical character."

Embree reviews present-day statistics on population and distribution of the American Negro, disease and death rate, education, types of labor and profession open to him, and his contribution to American culture. One closes the book with the feeling that in the future less emphasis should be placed upon past treatment of the Negro in this country. Rather should it be emphasized that here in our midst a new race has developed, that in its short life great progress has been made in the process of finding itself, and that in the long run it should fit into our scheme of things as other minority groups have done.

WESTERN CIVILIZATION: *The Decline of Rome to 1660. By Francis J. Tschan, Harold J. Grimm, and J. Duane Squires. Edited by Walter C. Langsam. J. B. Lippincott and Company, Philadelphia.* $3.25. 9 x 6; xciii + 783; 1942.

When the present reviewer was a school boy many years ago he studied English history. Here he learned that Alfred burned the hot cakes, that Canute forbad the tide to rise, that William of Normandy's coffin broke in two when forced into a grave too short for it, that Richard Coeur-de-Lion engaged in a boxing bout with Robin Hood, and that a well-meaning but uninformed valet emptied a bucket of water on Sir Walter Raleigh, who replied "Be of good cheer, for we shall light such a fire in England that it will never go out." He also learned that somewhere on the other side of the Strait

of Dover there was a mysterious hinterland from which at irregular intervals issued equally mysterious personages to trouble England's peace, with names like Innocent III, Joan of Arc, and Philip II. Like Melchisadek, king of Salem, these figures appeared to have neither beginning of days nor end of life. They disappeared from the scene like Henry Hudson's crew in the version of Rip van Winkle by Joe Jefferson.

But if at that remote period Tschan, Grimm, and Squires' *Western Civilization* had been available it would not have been necessary for the reviewer to confine himself to a meaningless list of kings and indecisive battles. Kings and battles occur in this work, it is true, but their importance is not exaggerated; they are like coordinate axes which serve only to fix the position of the really significant characters and events in history. Here one can read about Isidore of Seville, Augustine of Hippo, Gregory of Tours, Thorfinn Karlsefne, Averroës the Commentator, Albertus Magnus, Dante Alighieri, Roger Bacon, Michael Paleontologus, Leonardo da Vinci, Nicholas of Cusa, Prince Henry the Navigator, or Thomas à Kempis. Here one can read what happened to Henry IV at Canossa, to John Huss at Prague, or to Galileo before the Inquisition.

Suffice it to say that the reviewer keeps a copy of this book on the bedside table, and every evening reads from it for about an hour before turning out the light.

MARRIAGE AND FAMILY LIFE.

By Gladys Hoagland Groves. Reynal and Hitchcock, New York. $3.50. 8¼ x 5½; x + 526 + iv; 1942.

The author's many years of practical experience in writing, counciling and teaching in the field of family relations has well qualified her for the task of preparing this comprehensive volume. The work will be welcomed not only by the bewildered lover whose mind is torn between personal emotions, "friendly?" advice from friends and relatives, and the sense of mounting responsibilities at the thought of entering into the state of marriage, but also by those older couples, either happily or unhappily married, who are still attempting to make their marriage and family life yield a greater measure of personal satisfaction and joy.

The textual material is organized around three very logical elements of the marriage cycle, namely: (1) the family background of the individual; (2) the preparation for marriage; and (3) the adjustments in marriage. A fourth section lists excerpts from letters and case histories pertinent to each of the chapter headings.

In Part I, the author emphasizes the importance of normal home life (sympathetic and wholesome parental influence and guidance from birth through adolescence) upon the individual's ability to choose wisely and adjust easily in the consummation of the marital relationship. Part II carries a plea for the delicate balance between emotion and reason which is essential to success in choosing, courting, and betrothing the partner for life. The discussion in Part III provides equal consideration of the physical, emotional, religious and economic factors in successful marriage and family relations. The cases listed in Part IV give meat and substance to the theoretical considerations in the text, and furnish undeniable testimony to the efficacy of Mrs. Groves' methods in handling the miriads of problems which arise from man's stubborn (if sometimes futile) attempt to get along with himself and his fellows.

A valuable list of references for further reading is appended for each chapter heading, and an index is provided.

PUERTO RICO: *The Next State.*

By Bolivar Pagan. Washington, D. C. Free. 7½ x 5½; 108; 1942 (paper).

Bolivar Pagan is Resident Commissioner of Puerto Rico to the United States, U. S. House of Representatives. His book is written with the aim of acquainting American readers with Puerto Rico—the progress that has been made during the forty-four years of American régime, and the assimilation of American institutions and ideals in the way of living. In short, he seeks to show that Puerto Rico is now ready for statehood.

After an introductory chapter Pagan gives the statement of General Miles on "United States Policies and Attitudes toward Puerto Rico." He then discusses Puerto Rico's place in war effort in World War I, government, local politics, geography, Puerto Rican history, population, economic status including agriculture, sugar manufacturing, trade, commerce and transportation, and finally in an appendix he gives the Bill for Statehood which he introduced in the House of Representatives in April, 1940.

The population of Puerto Rico is of Spanish extraction; but, although basically Spanish, the people have become Americanized rapidly in the past forty-four years. The population has arisen from 44,833 in 1765 to 1,869,255 in 1940. More than three-fourths of the population is native-born white and nearly one-fourth is colored. Puerto Rico has a larger percentage of white people and a smaller percentage of colored than any other area in the Caribbean region. Literacy has steadily increased. In 1899, only 20.4 per cent of the inhabitants 10 years or older were able to read and write as compared with 68.8 per cent in 1940, illiteracy being highest among the older people. Health conditions have improved rapidly since 1900. At that time the birth rate and death rate were approximately equal. Since then, with improved living conditions, the death rate has been halved.

CHAVIN STONE CARVINGS. *Yale Anthropological Studies, Volume III.*

By Wendell C. Bennett. Yale University Press, New Haven. $1.00. 10¾ x 8⅛; 9 + 30 figures; 1942 (paper).

This publication has been issued to supply the existing literature on Chavin stone carving with more illustrative material and to bring to the attention of scholars the importance of the recent findings of this early Peruvian culture. The ruins of Chavin, as well as many other localities in Peru, exhibit many examples of these carvings. The designs are found not only on the carved stones in the ruins and among museum specimens in various places in Peru, but also on ceramics, bone, and shell objects on the North Coast, on gold work at Chongoyape in Lambayeque Valley, and on relief-decorated clay walls at Nepeña.

There are two kinds of stone carvings—round and flat. That they are related is indicated by the fact that they are associated *in situ* on the walls of the Castillo, and that there is a consistency in the general motif and a similarity in detail. In the round, the carvings are almost always of animal and human heads with "tendons" for wall insertion. Since the round carvings are better known, the present work is devoted to the flat carvings. The thirty illustrations are reproduced from the fine collection of drawings by the late Mr. Humberto Hidalgo who spent many months making tracings of decorated stones around Chavin. The flat carvings, of low relief, display great symmetry. The feline figure with appendages is the dominating motif. Variations in design introduce the condor-feline (with bills and wings) or the fish-feline (with tail and fins). The illustrated figures are accompanied by detailed descriptions. The author has provided a carefully chosen bibliography of 16 titles.

WORKBOOK MANUAL FOR MARRIAGE AND THE FAMILY. *By John Harvey Furbay. D. Appleton-Century Company, New York and London.* $1.50. 11 x 8½; 247; 1942 (paper).

This workbook manual is so designed that it can be used with any of the well-known texts in the field. The subject matter is well covered in 18 general sections and can be used for a one-semester course or extended to a full year's work.

As an example showing the arrangement of the material we give Section 11—on "Economic aspects of marriage." There is first a two-page general discussion of the subject and a page showing a sample budget and the actual budget and expenditures of a newly married couple making $100 a month. Then follow 3 blank pages for lecture notes; two pages of suggested reading (basic references, 6 titles; other references, 27 titles; and articles, 29 titles); two blank pages for notes on outside reading; and 4 pages of discussion questions (16 questions) with blank spaces to be filled in by the student.

FAMILY EXPENDITURES FOR EDUCATION, READING, RECREATION, AND TOBACCO. *Five Regions. U. S. Department of Agriculture Miscellaneous Publication No. 456. Consumer Purchases Study. Urban, Village and Farm Series.*

By Day Monroe, Dorothy S. Brady, Maryland Y. Pennell, and Miriam H. Coffin. Government Printing Office, Washington, D. C. 25 cents. 9⅛ x 5¾; v + 208; 1941 (paper).

ZOÖLOGY

FADING TRAILS. *The Story of Endangered American Wildlife.*

Edited by Walter A. Weber. Prepared by a Committee of the United States Department of the Interior National Park Service, and Fish and Wildlife Service. The Macmillan Company, New York. $3.00. 8¾ x 5⅜; xv + 279; 1942.

Fading Trails is a sermon, whose text is the story of the Garden of Eden. This story is told in the opening paragraph of the book but with a modern interpretation —that the sin for which our earliest progenitors were punished was Greed. "Adam's sons have followed in his footsteps." So comments the editor, who then continues: "Throughout the ages, since the days of Eden, they have killed the goose that laid the golden egg, eaten the seed needed to make the crop, and counted on a miracle of Providence to restore that which they willfully and wastefully destroyed." The explanation of why that species of *Homo* who does not deserve to be called *sapiens* is his own worst enemy can be expressed in a single word—Greed.

It was Greed that brought about the depletion of the Everglades, with the consequent disappearance of the crocodile and the kite, and the reduction of the alligator and the flamingo. It was Greed that destroyed the great auk and Arctic sea cow, and it was Greed that reduced the sea elephant and the sea otter to small colonies on Guadalupe Island and in Monterey county respectively.

A sad story is that which Daniel B. Beard has to tell us—sad not only from the standpoint of the victims of greed, but also for the thoughtful human being who realizes that the responsibility for the wanton destruction of so much wild life rests chiefly upon his own species—the proletariat committing the actual slaughter and the intelligentsia aiding and abetting them because, in the words of the poet, they "see the wrong

and fear to speak." Indifference may be just as effective as malice.

Everyone has heard the story of the passenger pigeon, that began in Audubon's journal in 1805 and ended in the Cincinnati Zoo in 1914. But how many have heard the voices of twenty-five other indigenous Americans crying "morituri salutamus" as the furriers and milliners drive them down the "River of no return"? For the passenger pigeon hope is dead, and a few brief notes in the introductory chapter alone serve to recall its tragic fate. The greater part of the book is concerned with the caribou, the ferret, the manatee, the trumpeter swan, the ivory-billed woodpecker, the terrapin, and the Atlantic salmon, to mention but a few. For it is not too late to save them even yet. The bison has been saved, and the shad is returning to spawn in the Hudson, if not in the Delaware. But on the whole the outlook is decidedly discouraging.

Among the assembly of vanishing races the editor has deemed worthy of mention only one invertebrate—the North Atlantic lobster. We wonder why the humble oyster, that favorite of Lucullus (to say nothing of the Walrus and the Carpenter), should not also have been included. For the oyster business represents a larger outlay of capital than that of the lobster, and its crop is diminishing with equal rapidity. Perhaps Mr. Beard does not enjoy Lynn Havens on the half shell as does the present reviewer. And as we read the writers' lament at the departure of the "snail hawk" from Florida, the result of the increasing scarcity of the Apple Snail on which it feeds, we notice that he sheds no tears for this noble mollusc, the sole representative outside the tropics of the family that contains the largest known fresh water snails, and which is of great interest in its own right, on account of its extremely isolated taxonomic position, its truly amphibious nature exemplified by the possession of both gills and a lung, the fact that in some species both shell and operculum are coiled sinistrally, and its beautiful clusters of pink and white eggs.

The reviewer also regrets that no mention is made of that remarkable mollusc *Tulotoma* formerly occurring in the Coosa river, which was lost beyond hope of recovery when that erstwhile turbulent stream was converted into a series of placid reservoirs to serve the power and light industries, or the equally singular genus *Io* of the Tennessee river which now faces a similar destiny.

In closing it may be pointed out that a similar situation exists in the vegetable kingdom. Each season the trailing arbutus is harder to find in the marsh lands of southern Jersey, and the wild columbine that formerly luxuriated in the Brandywine valley is now but seldom seen. The answer again is—Greed.

"The beaches of Lukannon shall know their sons no more."

THE PHOTODYNAMIC ACTION OF DYES ON THE EGGS OF THE SEA URCHIN, LYTECHINUS VARIEGATUS. *Tortugas Laboratory Papers, Volume XXXV.*

By David Hilt Tennent. Carnegie Institution of Washington, Publication 539, Washington, D. C. $1.25. 10 x 7; 153 + 8 plates; 1942.

In this final volume in the series of papers from the Tortugas Laboratory we have a compilation of the extensive experimental data obtained by the late Dr. D. H. Tennent during the years 1935–1939 when he was actively engaged in his researches on the photodynamic action of dyes on the development of the transparent egg of the sea urchin. The report falls into two parts: The first and the most detailed part deals with the effect, cytolysis, of the basic dye neutral red, on eggs before and after insemination. The second part is concerned with the testing of a wide variety of dyes, both acid and basic, for the production of photodynamic effects similar to those obtained with neutral red.

Briefly, the procedure was to transfer eggs from the stock to three finger bowls—one containing sea water, and two containing sea water plus the dye to be tested. One of the bowls containing the eggs in the dye solution was irradiated in sunlight for varying periods; the two controls were left in diffuse light or in darkness. The differences observed in the development of the eggs in the irradiated and the non-irradiated (control) cultures were interpreted as the result of the action of the sunlight on the dye bringing about the formation of a "photocompound". This photocompound Tennent regards as the active agent in the production of the observed "photodynamic effect" which resulted in two kinds of abnormalities in the irradiated cultures: (1) the production of blister cytolysis and (2) the inhibition or modification of cell division.

Numerous experiments were carried out to determine the effective concentration of the dyes, length of exposure, the intensity of light necessary to bring about the toxic effects, effective wave lengths, optimum temperature, etc. Much of the material was fixed and studied cytologically.

The most striking photodynamic effects were produced by neutral red. Other dyes giving similar effects were: Janus green B (diazine green), Congo red, thianin, brilliant cresyl blue, resorcin red, Nile blue A, cresyl violet, safranin O, Magdala red echt, brilliant green, basic fuchsin, pyranin, rhodoamine B, acridine. Some giving rather limited or slight effects were: methylene red, nigrosin, auramin O, picric acid, phyloxine. Eosin Y and fluorescein produced a photodynamic effect only when the eggs were uninseminated. These dyes apparently failed to penetrate the fertilization membrane. No photodynamic effect was produced by Martius yellow, alizarin red and rosolic acid.

There is practically no discussion of the extensive and varied observations included in this report. While

it is a good thing to have the data made accessible, it is to be regretted, indeed, that Tennent's speculations concerning the interpretation of the data were not recorded before his death.

THE OVERFISHING PROBLEM.

By E. S. Russell. Cambridge, at the University Press; The Macmillan Company, New York. 7s. 6d. 7⅞ x 4¾; viii + 130. 1942.

Russell, Director of British Fishery Investigations in the Ministry of Agriculture and Fisheries, reviews, in this series of De Lamar Lectures delivered at The Johns Hopkins University in 1939, the history of fishery activities within recent times and the development of investigations on the effect of over-fishing, and points out the importance of immediate international action as soon as war hostilities end in order to bring the fishery trade to a high level of efficiency while at the same time preventing depletion of stock.

In 1714, during the first reign of George I an act regulating sea fishing was passed which Russell says "forstalls in a remarkable way the provision of the existing legislature in Great Britain, which came into force more than 200 years later—in 1933 to be exact. . . ." Briefly the law required regulation of mesh and size limits for the principal species of fish. The original law appears not to have been enforced, and in 1868 it was one of "fifty or so fishery Acts" wiped out on the advice of the Royal Commission. Within the last 50 years or so, however, with the rapid depletion of old fishing grounds in the North Sea and the necessity of operating far from home for increased yields there has been a gradually developing effort by those countries bordering the North Sea to probe deep into the problem of fish conservation.

The problem is an exceedingly intricate one, requiring repeated checking of results and the study of each species of fish from a biological and an ecological angle. The study of fluctuations alone is a highly complicated problem. The cause of big variations in yield is now known to be bound up with good and bad brood years. The herring furnishes a good example. An enormous production of fry in 1904 was followed by good catches for many years later, to be followed by dwindling supplies until another good brood year occurred when the yield turned upwards again. Undoubtedly a combination of events determines the type of brood year.

Russell discusses particularly the bottom-lurking fishes such as cod, haddock, plaice, soles, skate and ray. Such species are not found fairly evenly distributed over the ocean bottom but live in certain areas, characterized by the same kind of bottom, as members of closely similar biological communities. It is these fish that are of special concern to the fishery investigators. On the accumulated results of research for each of these forms it is possible, Russell believes, to enact regulations of an international character which will prevent a serious reduction of fish stocks in the seas. It is a problem which confronts not only the countries of Northern Europe but is of immediate concern to all countries of both hemispheres.

The volume contains much statistical data throughout the text, also graphs, and a list of the more important treatises concerning the fishing problem. An adequate index is provided.

MY FRIENDS THE APES.

By Belle J. Benchley. Little Brown and Company, Boston. $3.00. 8 x 5¼; xv + 296 + 25 plates. 1942.

It frequently happens that the author of a successful book fails to maintain in subsequent writings the high standard set by the first one. This does not apply to Mrs. Benchley. When *My Life in a Man-Made Jungle* established its author's reputation it was inevitable that other books should appear from her pen, if only to satisfy the impatience of her readers. *My Friends the Apes* does just that, but it also does a lot more. It is on a distinctly higher intellectual plane than the earlier work, which was addressed to the same sort of audience that attends the talks that the author gives before business and social clubs, where her services are in demand.

In her preface Mrs. Benchley tells us that the present book is not intended for scientific readers. By this the reviewer understands that she did not have a scientific audience in mind while writing—she was thinking of the casual visitor who enters the zoo out of curiosity, in whom she wishes to evoke the desire to understand the animals as well as to be amused by them. But to understand the anthropoids it does not suffice to know them collectively; one must be acquainted with them individually. Not only is the personality of the gorilla widely different from that of the gibbon, but the personality of one gorilla differs observably from that of another. The fact that Mrs. Benchley has not written about apes in the abstract gives her work real scientific value, and when she tells us that it is not a scientific book, she libels her own product.

In popular but accurate language the author tells the stories of all the anthropoids in the San Diego Zoo, where five genera are represented. This is not the largest zoo in the country, but it is one of the best equipped, and its unusually large cages, and the fact that the animals can remain out of doors all the year round make it ideal for the study of animal psychology and sociology. These subjects are of interest not only

in their own right but because they furnish the needed comparative background without which the corresponding human sciences cannot become intelligible. When zoo visitors ask the author if her observations indicate the descent of man from monkeys, she is always tempted to reply that the comparison of the intelligence of the apes with that of some of her interrogators seems to indicate that the development of man has indeed been a descent.

Mrs. Benchley does not confine her narrative to Mbongo and Ngagi, Maggie and Mike, Shorty and Susie, and Old Mom and Blackie. She is well known in every zoo in North America both by the staff and the inmates, and she is thoroughly familiar with the literature of the subject. Consequently her book is not only a record of personal experience but an exhaustive treatise that reads like a conversation.

The book will be equally at home in the laboratory or on the parlor table, in the school or on the nursery shelf, and is not likely to be put down unfinished.

NESTING BIRDS AND THE VEGETATION SUBSTRATE.

By William J. Beecher. Chicago Ornithological Society, Chicago. $1.00. 9 x 6; 69; 1942.

This study of nesting birds relative to the vegetation substrate was made on a 482 acre tract consisting of marsh, prairie, woodland and cultivated fields in northeastern Illinois. The writer describes the plant communities of the area thoroughly, listing the plants for each of the four associes that he recognizes, and for each of their seral stages. In classifying these ecological realms however, he fails to consider any animals other than the birds.

The density of bird life is annotated in a list that gives the number of nests per acre of a certain vegetation type, and the number of acres per nest. These densities the writer attempts to correlate with the amount of feet of edge, and concludes that the population density of most nesting birds varies as a direct function of the amount of edge per unit area. How this conclusion was arrived at is not entirely clear from the data presented, especially not from Figure 3 which is supposed to show a "definite positive correlation". More pertinent are the data that indicate a better relationship between nest density and the variety of communities or floristic complexity within the unit areas.

Other results show that those species nesting earliest in spring are birds whose nests show them to be independent of vegetation of the year. In the discussion of breeding distribution of birds, it is considered that the vegetation substrate is the prime determiner in any limited local environment. Birds nest in communities of the type best suited to an inherited pattern. Changes imposed in nesting habit by man are believed to be nothing more than range extension of original patterns to newly opened habitats.

The wealth of data presented in this little volume makes it a valuable contribution to the subject of bird populations.

ADAPTIVE MODIFICATIONS FOR TREE-TRUNK FORAGING IN BIRDS. *University of California Publications in Zoology, Vol. 46, No. 4.*

By Frank Richardson. University of California Press, Berkeley. 75 cents. 10¼ x 6⅝; 317–368 + 1 colored plate; 1942.

For the student of evolution and comparative anatomy this rather thorough analysis of anatomical modifications from the point of view of their adaptive value will be of special interest. Correlation of form and function is so universal among animals that it has been known since the beginning of biological science. Only recently, however, have specialized structures that are correlated with functions been analyzed in terms of their mechanical aspects and their rôle in evolution. Parallel structural adaptations of several groups of birds having the same habit of foraging on tree trunks are compared. Previous studies of this kind have often dealt only with the skeletal system, whereas the chief aim in this paper is a detailed evaluation of parallel adaptation shown in interrelated structures or organ systems.

Since the present study concerns the comparison of unrelated species, representing families from two orders of birds with similar habits, it is essentially a consideration of convergent or of parallel adaptation, particularly the latter, because the structures compared are homologous. The following species were selected for study: Downy Woodpecker, Barred Woodhewer, White-breasted Nuthatch, Brown Creeper, and Bewick Wren.

The use of quantitative comparisons has shown that often only a slight quantitative modification may be of adaptive significance. This would not be apparent if qualitative methods alone had been employed.

BIRDS ACROSS THE SKY.

By Florence Page Jaques. Harper and Brothers, New York. $2.50. 8½ x 5½; xii + 240; 1942.

It has been said that bird lovers, like musicians, are born and not made, but in this very delightful book of Mrs. Jaques we have a shining example of how one bird lover was made. The author admits that as an undergraduate she had been amused by the silent little groups of budding ornithologists standing intently beneath the campus trees with their binoculars and blithely pronounced them "oddities". Even when she married a bird artist she did not realize how continuously she was to flock with birds.

Her entertaining and rather humorous accounts of her difficulties in learning to identify birds and to love them with a real appreciation should strike an encouraging note in many of us who would like to know more about birds but do not know exactly how to begin.

Much of the book is concerned with descriptions of the many trips which the Jaques took in pursuit of birds of all kinds. In Minnesota, as a climax to years of journeying, they saw the "tremendous and exalting" drama of two migrations of pintail ducks and blue geese, and realized that they were witnessing "one of the great sights of the world".

The book is tastefully illustrated with delightful pen and ink sketches by Francis Lee Jaques, of the American Museum of Natural History, who is the artist-husband of the author. He is regarded as one of the best bird portraitists working in America today.

GENERAL ZOOLOGY LABORATORY GUIDE.

By J. E. Wodsedalek. John S. Swift Company, Missouri. $2.75. $2.00 for guide for one semester. 11 x 8½; 298; 1940 (paper).

This guide is intended for use in the college or university introductory course. In order to facilitate the making of drawings, in many instances outline drawings are provided, and the student is at liberty to draw in certain details primarily for his own record. Many diagrams are included which are intended to help clarify parts of laboratory exercises which have proved, in the experience of the author, to be perennial "stumbling blocks". The text figures are also employed to replace lengthy and frequently none too clear printed directions. Following the study of the unit structure of protoplasm, the cell, and the different types of tissues as composed of differentiated cells and their products, the guide proceeds to treat the animal life in phylogenetic order—from simple to complex. The manual attempts to incorporate the desirable features of both the "type" and the "principle" plans of study in the laboratory procedure. There is ample material for a full year's course and an effort has been made to adapt it for use in connection with any of the more modern standard textbooks of college zoology. The numerous and excellent drawings, all of which are the original work of the author, are a striking and particularly noteworthy part of the guide and should prove of material value to the student and instructor alike. Space is provided for the taking of notes. A very helpful chapter on the elements of chick embryology has been included.... There is no index or bibliography.

GENERAL ENTOMOLOGY.

By S. W. Frost. McGraw-Hill Book Company, New York. $4.00. 9 x 6; x + 524; 1942.

This elementary text for college entomology is rather unusual in its great emphasis on the habits and ecological relations of insects and its neglect of morphological and taxonomic subjects. Classification is given only the briefest consideration, physiology is hardly mentioned, and the chapter on insect morphology is concerned almost exclusively with external characters. The main body of the book is therefore chiefly occupied with consideration of subjects which are often quite omitted or only sketchily treated in ordinary entomology texts. Insect behavior, insect associations, and specialized habits, like leaf-mining, leaf-rolling and casemaking, are taken up very fully in a most interesting and original way and individual chapters are devoted to the gall insects, the boring insects, subterranean insects, aquatic insects and so on. Each chapter of the book is accompanied by a useful bibliography of general papers and the illustrations, many of which are original, are very good. The book is well-written and stimulating, and an effort is made to train the student to make observations in the field. Its approach to the subject may not, however, be well adapted for the needs of the average entomology course, especially where no opportunity for advanced work in this subject is provided.

ZOÖLOGICA. *Scientific Contributions of the New York Zoölogical Society. Volume XXVII, Part 2, Numbers 9–16.*

New York Zoölogical Society. Zoölogical Park, New York. 75 cents. 10½ x 7; 45 + 9 plates; 1942 (paper).

This number contains the following papers: Notes on Tschudi's types of Peruvian birds, by Herbert Friedmann and H. G. Deignan; A revision of the kingfishers, *Ceyx erithacus* and *rufidorsus*, by S. Dillon Ripley; On the reproduction of *Gobiosoma robustum* Ginsburg, by C. M. Breder, Jr. (2 plates; 1 text-figure); *Trichodina spheroidesi* and *Trichodina halli* spp. nov. parasitic on the gills and skin of marine fishes, with special reference to the life-history of *T. spheroidesi*, by Morton Padnos and Ross F. Nigrelli (3 plates; 4 text-figures); Mortality of albino embryos and aberrant mendelian ratios in certain broods of *Xiphophorus hellerii*, by Myron Gordon (1 text-figure); The schooling behavior of mackerel: A preliminary experimental analysis, by Arthur Shlaifer (1 plate); Food, eggs and young of the carnivorous snail, *Euglandina rosea* (Ferussac), by William Marcus Ingram and Walter Edward Heming (1 plate); The anatomy and morphology of the hypophysis of several species of ovo-viviparous Poeciliids, by Hugh E. Potts (2 plates).

BIRD PORTRAITS IN COLOR. *Two hundred ninety-five North American Species.*

Text by Thomas S. Roberts. Illustrated with ninety-two color plates by Allan Brooks. The University of Minnesota Press, Minneapolis; Oxford University Press, London. $3.50. 11 x 8½; pages unnumbered; 1940.

Among popular bird books this collection of bird illustrations taken from *The Birds of Minnesota* is outstanding. Although this set of plates was prepared to illustrate a work on Minnesota birds and in a strict sense is representative of the bird-life of the upper Mississippi Valley and adjoining parts of Canada, it applies to a very considerable extent to all the northern United States and Canada east of the Rocky Mountains. As a picture book for the youngest members of the family, a guide for boys and girls in school and in camp, an aid to teachers and recreation leaders, and a companion to bird lovers everywhere, it will prove an endless source of inspiration and delight. The brilliancy and accuracy of color reproduction in the ninety-two full-page illustrations is commendable.

The text is largely new and includes a brief description of each bird depicted, giving its size and distinguishing characteristics, its range, its most interesting habits, the type and location of its nest and the color of its eggs.

DISTRIBUTION AND VARIATION OF THE HORNED LARKS (OTOCORIS ALPESTRIS) OF WESTERN NORTH AMERICA. *University of California Publications in Zoology, Vol. 46, No. 3.*

By William H. Behle. University of California Press, Berkeley. $1.25. 10¼ x 6⅝; 205–316; 1942 (paper).

This paper is a rather important contribution to an understanding of the species problem in birds. In dealing with a revision of the genus *Otocoris*, the main objective has been to describe the observed facts of variation and to correlate these facts, wherever possible, with physiographic features in the ranges of the individual races. From such a procedure pertinent information has been gained which furthers our knowledge of the factors operative in the process of species formation in this particular bird. From this study it is obvious that the many described races of Horned Larks are far from being the precise units that our nomenclatural system would indicate. There is frequent and extensive intergradation between the races within which there is marked individual variation. The importance of such factors as natural selection, geographic isolation, environmental change, and hybridization in bringing about subspeciation are carefully considered.

THE SEASHORE PARADE.

By Muriel Lewin Guberlet. Illustrated by Jan Ogden. The Jaques Cattell Press, Lancaster. $1.75. 7½ x 5½; 197; 1942.

An introduction to all the larger invertebrate phyla, the age group to which this book is addressed is well indicated by the following quotation: "When danger is near the anemone draws the pretty feelers into the stalk and closes the door of his house. Then he appears old, ugly and wrinkled. The change is like Cinderella who lost all her finery at the stroke of twelve."

The book is carefully written and quite accurate scientifically, although there is one slip, where the author refers to the little crab which lives symbiotically in the oyster shell as "he". Most carcinologists agree that only the female has acquired this commensalistic habit.

The book is well illustrated with both drawings and colored plates, and the amount of information which it contains is astonishing.

IN QUEST OF GORILLAS.

By W. K. Gregory and H. C. Raven. The Darwin Press, New Bedford. $3.50. 9¼ x 6⅛; xvi + 241; 1937.

An entertaining account, by two well-known explorers and naturalists, of an expedition sent out by the American Museum of Natural History and Columbia University in 1929 to tropical Africa with the aim of bringing back a perfect specimen of an adult gorilla. The gorilla had learned by bitter experience to be wary of hunters and the members of the expedition had many experiences during their months of searching. A day by day description is given of their travels and much interesting reading is furnished in their stories of native life.

A pleasant book which nicely offsets serious reading matter of today.

APPLIED ENTOMOLOGY; *An Introductory Textbook of Insects in Their Relations to Man. Fourth Edition.*

By H. T. Fernald and Harold Shepard. McGraw-Hill Book Company, New York. $3.50. 9 x 6; viii + 400; 1942.

Recent advances in insect control have necessitated a revised edition of this well-known reference book. The fourth edition has been brought up to date by including the new insecticides and other recent methods of control, by the addition of new insects of economic importance, and by rewriting and revising other chapters. Illustrations have been added and some of the older worn-out figures have been replaced.

STUDIES ON FRESH-WATER BRYOZOA. XII. A Collection from Various Sources. *Annals of the New York Academy of Sciences, Volume* 43, *Art.* 3.

By Mary D. Rogick and Claudeous J. D. Brown. New York Academy of Sciences, New York. 9¼ x 6½; 21; 1942 (paper).

SENSORY CUES USED BY RATTLESNAKES IN THEIR RECOGNITION OF OPHIDIAN ENEMIES. *Annals of the New York Academy of Sciences, Volume* 41, *Art.* 5.

By Charles M. Bogert. New York Academy of Sciences, New York. 9¼ x 6½; 14; 1941 (paper).

THE NATURAL HISTORY AND CLASSIFICATION OF THE MOUNT LYELL SALAMANDER, HYDROMANTES PLATYCEPHALUS. *University of California Publications in Zoology, Vol.* 46, *No.* 2.

By Lowell Adams. University of California Press, Berkeley. 35 cents. 10¼ x 6⅝; 179–204 + 1 plate; 1942 (paper).

BOTANY

FOREST TREE SEED *of the North Temperate Regions with Special Reference to North America. Volume VIII in a New Series of Plant Science Books, edited by Franz Verdoorn.*

By Henry Ives Baldwin. Chronica Botanica Company, Waltham, Mass.; G. E. Stechert and Co., New York. $4.75. 10¼ x 6⅝; xvi + 240; 1942.

In its detailed and adequate treatment of an important field but little emphasized hitherto in English, this book is especially timely now when conservation and reforestation will be needed both because the unusual demands of our war efforts may deplete our own supplies, and because the Scandinavian countries, long the leaders in forest production, have been subjected to systematic and vicious despoilation. Although highly technical, the book is enlivened by occasional apt quotations as chapter headings; several neat line drawings as tailpieces and as attractive, unnumbered, but pertinent sketches add charm to the text; while a brief biographical sketch of Dr. Baldwin is helpful and informative for those who do not know the author's background and work. The book covers the subject matter unusually thoroughly considering the several technical fields comprised, while the bibliography serves as an extensive and substantial supplement. The practice of listing the literature references at the end of the first chapter in which they occur places them where they are most pertinent and effective, and offers little if any difficulty since the author index includes references not only in the text but also in the literature lists of each chapter.

The figures, some original, others from various sources, comprising graphs, schematic diagrams, and line illustrations helpfully support, clarify, and enhance many parts of the text, being especially useful in supplementing the descriptions of complicated apparatus for the extraction, cleaning, and germination of seeds.

Approximately half of the book is devoted to tree seeds, emphasizing especially their collection, their extraction, cleaning and treatment, their storage and longevity, and their destruction by insects, diseases, and other enemies, but also covering in some detail the structure and development of seeds, the problems of seed production, and the importance of seed source. The second half is concerned with germination, its nature, the internal and external factors affecting it, the physiological and chemical aspects involved, but discusses also methods of seed stimulation, various tests and analyses for viability, germination, origin, and purity, and considers seed testing stations and seed certification. Finally, there is a short chapter on tree seed research, outlining briefly the procedure, the method, and the literature involved, and showing the need for future investigation. Considering the productivity of the author himself and his long and close contact with progressive research in forestry, this chapter is somewhat disappointing, for the single paragraph on fields for future seed research merely cursorily notes a few of the important possibilities. Fortunately, however, throughout the book many significant problems much in need of solution are implied if not specifically stressed.

The book fills a definite need, and is a welcome addition to the highly practical yet scientifically sound and authoritative treatments of various aspects of the plant sciences that have appeared in recent years. In the book there is little to criticize;—yet the use of *seed* both as singular and as plural is sometimes discomfitting even though condoned by Webster. Also, the setting of much of the text in small type rather disconcerts the reader by interrupting his train of thought, especially as this seems to follow no fixed plan, neither of relegating subsidiary material to the smaller type, nor of covering in more detail material introduced and outlined in general terms in larger type. Furthermore, less gifted readers (such as this reviewer) will find somewhat puzzling such untranslated headings (cf. maps, p. 17) as "176 kottprov av gran insamlade hösten 1921". The glossary is a useful adjunct. Indeed, it is not only useful but practically essential if the uninitiated reader is to understand such terms as "scalping shoe", "provenance", "ecesis", and "disseminule". Having mastered these, it will perhaps be something of an anticlimax to him to find that a seed dealer is "a seed merchant, or one who buys and sells seeds". As terms commonly defined in textbooks are not included in this special glossary, the reader may wonder why "mulch" is included and not "duff". The inclusion

in the glossary of French, German, and often Swedish, Danish, and Norwegian equivalents is helpful to the reader. Indeed, the French equivalent of "ecesis"—"adaptation à un milieu nouveau"—seems far clearer than "ecesis" itself.

The two-page index of plant and animal names included in the book is helpful and the three-page author index especially so, as by means of it one can locate the literature references accompanying the separate chapters. As an example of the completeness and usability of this author index, note that it includes T. D. Lyssenko, who appears only in the glossary under Jarovisation.

The book is an able, well organized, and scholarly work; the survey of the scattered and rather inaccessible literature is given authoritative effectiveness through the long experience and first hand knowledge of the author; the original work of the author ably supplemented by additional material made available to him by others in the field still further increases the value of the book.

ECOLOGICAL CROP GEOGRAPHY.

By Karl H. W. Klages. The Macmillan Company, New York. $4.50. 9¼ x 6; xviii + 615; 1942.

Although written by an agronomist as a guide to the many factors which affect the cultivation of crop plants, *Ecological Crop Geography* contains much which will be useful to students interested in ecology, plant distribution, economics, and human geography. The field covered is so broad that the material in each of the chapters is necessarily in the nature of a summary. Nevertheless, it is concisely and clearly written, and the extensive bibliography should satisfy any student who feels the need of more information on the subject. Many maps, graphs, and tables are provided.

Klages has organized his material into four sections which deal respectively with the social environment of crop plants, a generalized discussion of the physiological environment, ecological factors, and the distribution of specific, agronomically important crops.

The section on the social environment of crop plants is introduced by defining the scope of ecological crop geography. A description of the agriculture of primitive peoples and the evolution of modern systems of cultivation make an interesting background for a discussion of present agricultural practices. The conflict between agricultural specialization and the self-sufficiency aims which intense nationalism tends to produce is pointed out. The effect of transportation facilities on the economic feasibility of crop production is profound and the ease or difficulty of crop production in various parts of the world has had a tremendous effect on population. The population centers of the world are closely correlated with intense agricultural activity. Centers for white and colored races and possible future centers are pointed out. Temperature and humidity are the two most important factors in determining the fitness of a region for human occupation, and these factors may thus affect agriculture adversely in areas which would otherwise be favorable.

Different plants vary in their physiological requirements, and every species shows a minimum, optimum, and maximum tolerance for the intensity of a given environmental factor. Any single factor which exceeds the maximum or minimum intensity at the most critical stage of development of the plant will be a barrier to the development of that plant. Since environments on the earth vary greatly, different plants have responded by becoming adapted to different ecological optima. It follows that similar environments will produce similar types of vegetation and will limit the development of others. The effect of variations from the ecological optimum is illustrated by giving the yields and variabilities in yields of important cereal crops in the grain belt of the United States. Recognition of the principles involved would have prevented the disastrous erosion and dust storms which the drier areas of the Great Plains experienced several years ago. These principles must be observed in the future if our soil resources are to be efficiently used and conserved.

The third section places emphasis on an analysis of various environmental factors and their distribution, although the relationship of these factors to plants is also, of necessity, brought in. Moisture, temperature, and light are regarded as the three most important factors of the physiological environment. The various possible combinations of these and physiographic factors produce a wide variety of climates which are classified according to schemes evolved by several authorities on the subject. Climate is treated from the causal point of view as well as from the purely descriptive. Its profound effect upon plant distribution is pointed out and illustrated.

Finally, the growth habits, requirements, uses, distribution, and relative importance of specific crop plants are described. The crops discussed include the cereals, edible legumes, root crops, sugar producing plants, oil producing plants, fiber crops, and forage crops.

Ecological Crop Geography will be useful as a text in agricultural schools; it is a valuable reference for botanists, economists, and geographers.

DISEASES OF BRITISH GRASSES AND HERBAGE LEGUMES.

By Kathleen Sampson and J. H. Western. Cambridge, at the University Press; The Macmillan Company, New York. $1.50. 9¾ x 6¼; vi + 85; 1941 (paper).

This technical British booklet, a valuable addition to its field, is available in this country through the Mac-

millan Company. Within its space limits, it is notably complete and adequate, competently fulfilling its stated purpose primarily of rendering accessible descriptions of the structure, development, and activities of the several fungi attacking agricultural grasses and clovers in Britain, and secondarily of appraising the relative importance of these several parasites. Although to some extent the injurious agents discussed differ from those destructive in the United States, yet, in the main, there is more than enough agreement to render this booklet of great value here.

The illustrations comprise 8 full-page plates of excellent half-tones, some new, some taken from previous publications, helpfully supplemented by 15 text figures. In suitable balance, 30 pages are devoted to diseases of grasses and 25 to diseases of herbage legumes, while diseases of turf and miscellaneous diseases due to mineral deficiency make up the remainder. An especially valuable part of the publication is the bibliography of 315 references, bringing together from technical periodicals and other sources in English, French, German, and other languages the literature in the field for the last 20 years. A very workable index, in which the names of genera, both hosts and pathogens, stand out in bold-face type, comprises both scientific and common names and renders quickly accessible the detailed material condensed in the 85 pages of text.

The excellent quality of the half-tones on highly calendered paper is evidence of the best workmanship, while in keeping with the high standards of the Cambridge University Press there is a notable freedom from typographical errors, the whole report, in form and content, setting us an admirable example of what can be accomplished under adverse conditions.

The booklet has the sound and authoritative basis of the results of more than 20 years of field and laboratory research at Aberystwyth, chiefly by Miss Sampson, and of an extensive survey throughout Britain by Western for the Ministry of Agriculture. Applied to this material is a thorough knowledge of the extensive literature hitherto widely scattered and difficult of access. Much original work by Miss Sampson is included, some of it already known from publication in the *Transactions of the British Mycological Society*, some not previously presented. Her detailed account of *Epichloe typhina*, causing the choke disease of various grasses and grains, will be of special interest to mycologists in this country.

In addition, this report is an inspiring example of the indomitable spirit of the British, their scientists completing valuable work despite shortages and obstacles; their scientific groups such as, in this instance, the Mycological Society and the Agricultural Research Council supporting publication despite financial difficulties.

THE NATURE AND PREVENTION OF PLANT DISEASES. *By K. Starr Chester. The Blakiston Company, Philadelphia.* $4.50. 9¼ x 6; xii + 584; 1942.

A new and comprehensive text-book of plant pathology, with emphasis on the practical aspects of disease control, should find a welcome among agricultural schools, farmers, and county agricultural agents. Leading diseases of American crops are treated in detail, but less important ones are also given attention. There are more than two hundred illustrations and diagrams, a large index, and references at the end of each chapter.

The first chapter of the book is devoted to a discussion of the significance of plant disease in agriculture. Specific examples of serious epiphytotics of the past are described in relation to their influence on human affairs and on the development of the science of plant pathology. It took several major epiphytotics to awaken interest in plant disease in Europe; it took another epiphytotic which has practically exterminated one of our finest forest trees, the American chestnut, to establish the science of plant pathology in America.

A general discussion of the types of plant diseases is followed by a large section in which individual diseases are given specific attention. Major diseases are systematically treated according to the following outline: history and distribution, importance, host plants, symptoms and signs, etiology, epiphytology, and control. Where resistant varieties are known, these are named, and the degree of resistance is given. The order in which the various causal agents of disease are treated is unusual. Rusts are considered first, followed by smuts, fleshy basidiomycetes, mycorrhizae, ascomycetes, imperfect fungi, phycomycetes, bacteria, viruses, parasitic seed plants and algae, nematodes, and physiological factors. All are given extensive treatment, and a special chapter is devoted to damping-off and related phenomena.

The more general discussions, which are usually regarded as introductory in nature, are here placed at the end of the book. A description of methods of studying plant diseases includes formulae for preserving specimens, culture media, and methods of growing disease organisms on artificial media and on living host plants. Extensive references to diagnostic literature are included. There is an excellent discussion of the relation between environment and the development of plant disease. Control measures are described in detail and attention is paid to their effectiveness and economic feasibility.

The Nature and Prevention of Plant Diseases is a well written, carefully organized, and valuable contribution to its field.

DENDROCHRONOLOGY IN NORTHERN ALASKA. *University of Arizona Bulletin, Volume XII, No. 4. Laboratory of Tree-Ring Research Bulletin No. 1.*

By J. L. Giddings, Jr. University of Arizona and the University of Alaska, Tucson, Arizona. 9 x 6; 107; 1942 (paper).

The growing importance of dendrochronology in solving many archaeological problems need scarcely be emphasized. In this report Giddings shows the value of the technique in determining the presence of identity of ring sequences in Alaskan wood buried in frozen silt deposits, in living trees (in the vicinity of Fairbanks, along the banks of the Yukon and Tanana rivers, and from the northern "tree line") and in driftwood (from western arctic coasts).

Cross-dating, the tracing of identical time periods from one tree to another by means of ring patterns, is based upon the tendency of trees to reflect climate in the thickness of the annual growth ring. Trees growing under certain conditions add a thick layer of cells during a favorable season, but when the season is shorter or less favorable than usual with respect to precipitation or temperature the ring is likely to be thin—even microscopic or locally absent. Variations in ring thickness of this sort, when they occur in a large number of trees in a sizable area, constitute the working material of dendrochronology.

More than 3,000 specimens of arctic wood were studied, including several hundred wooden artifacts and fragments from the extensive archaeological collections at the University of Alaska. It was found that the ring record is uniform and sensitive among those trees of the timber line and the margins of large rivers. In the muskeg areas the record is often distorted and practically worthless. A strong correlation was found to exist between the tree-ring record and mean June temperature for both interior timberline and latitude timberline. A high degree of cross-dating was shown between groups of trees at timberline as much as 500 miles apart. It was also possible to determine the dates of certain Eskimo dwelling sites by applying the tree-ring technique to driftwood.

From the results already obtained Giddings believes that it will be possible to solve many interesting problems on silt deposition, dating of early Eskimo ruins, early climatic conditions, and the tracing of ocean currents. In a series of 33 tables data are given on tree growth, 22 figures show curves for temperature, precipitation, tree growth, etc., while 15 photographic plates show details of subjects discussed in the text. The author includes a useful bibliography.

DECIDUOUS ORCHARDS.

By William Henry Chandler. Lea and Febiger, Philadelphia. $4.50. 9¼ x 5¾; 438; 1942.

Tree processes, responses and relationships are used as the basis for the discussion in this text. Since the trees are grown for fruit, processes in the setting and development of fruits and the processes of mature fruits are discussed first, then orchard influences that affect these processes. Next orchard species are discussed: their relationship to each other, special aspects of their fruits and fruiting processes, and special responses to orchard environmental influences. In order to aid the student's memory, each part is made to stand out as boldly as possible and an attempt is made to arrange chapters and parts of chapters by relationships so that each new fact will assist in fixing the preceding one in his mind. There is a very considerable amount of repetition in the book, but the author feels that it is justified because of the very nature of the subject and because of the permanent benefit of such repetition to the student. In order to give the text as much unity and order as possible, only deciduous trees are considered. Some of the more interesting chapters have to do with: materials essential for growth of trees and fruit, the tree and the variety, flower bud formation, the growing and mature fruits, propagation of deciduous orchard trees, deciduous tree roots and the soil, nutrients for trees, the water supply in tree and fruit, responses of trees to pruning, stone and pome fruits, and nut trees. References and reading lists are provided at the end of many of the chapters. The book is well illustrated with excellent photographs and diagrams. A complete index concludes this noteworthy addition to the field of pomology.

AN INTRODUCTION TO THE PLANT SCIENCES.

By William C. Darrah. John Wiley and Sons, New York. $2.75. 9 x 6; xi + 332; 1942.

Disregarding the conventional methods of writing botany texts, the author has approached the topic from an organismal point of view by stressing the interrelationship of functions and minimizing classical morphology and taxonomy. The purpose in view is to make the subject interesting as well as instructive to students taking a half-year course in botany and who plan no additional work in the field. Although many topics have been omitted, the context has been well selected to provide a sufficient survey of the field. Illustrations have been reduced to a minimum as the author believes that they detract from the readability of the text.

LABORATORY MANUAL FOR STUDENTS OF AGRONOMY. *Third Edition.*

By L. F. Graber and H. L. Ahlgren. John S. Swift and Company, St. Louis. $2.00. 11 x 8¾; 155; 1942 (paper).

This excellent *Manual* is now in its third edition. The exercises are supplementary to a general survey of plant science for college students in which emphasis is placed on the application of biological fundamentals to agro-

nomic practice. In each exercise many questions are asked (space is provided for written answers), outlines of plant parts are provided, which are to be completed by the student, and a series of graphs and maps show the distribution of crops, land utilization and other statistical material. Included also is a section on measures and calculations involved in farm transactions and operations, and systems of weights and measures used in the United States are discussed.

A MANUAL OF SPICES. *What they are; Where they come from; How to use them.*

By the Research and Information Bureau. American Spice Trade Association, New York. 10 cents. 9⅛ x 7⅜; 15; 1942 (paper).

This little manual will form an interesting addition to the housewife's collection of cookbooks, although it is in no sense a cookbook. Much information is given that is not ordinarily available on the source of spices, part of the plant used, and in what dishes the different spices will be found agreeable as flavoring.

MORPHOLOGY

BIOLOGICAL SYMPOSIA. *Volume VII. Visual Mechanisms.*

Edited by Heinrich Kluver. The Jaques Cattell Press, Lancaster. $2.75. 9½ x 6¾; viii + 322; 1942.

This volume is a compilation of twelve papers on various fields of vision which have been built around a nucleus of eight papers presented in the *Symposium on Visual Mechanisms* at the fiftieth anniversary celebration of the University of Chicago.

The majority of papers (7) deal with various problems involving the nervous mediation of visual images. This type of work is basic to any understanding of vision, and significant advances are being made in elucidating various phases of the nervous physiology involved. The results, however, tend to explain in detail limited phases of the problem rather than to give a generalized picture, but as work on each of these specialized problems advances, more and more correlations may be found which will provide answers to general visual problems.

Papers by Wald and by Krause deal with problems of the chemistry of the retina and the cycles of chemical changes involved in vision, adaptation, etc. In the latter of these two papers, however, one is somewhat disappointed by the extensive discussion of substances isolated from the retina which is based only on reference to unpublished data. The absence of any concrete figures on the experiments referred to makes it extremely difficult for the reader to determine the significance of the results.

Two papers by Polyak and Walls deal with the anatomy of the retina, the latter considering the rods and cones from the standpoint of their evolution. Starting with the simple cone, which he considers to be the most primitive type of visual cell, Walls traces the evolution of the various types and combinations of visual cells found in the retinas of living vertebrates.

The symposium is completed with a paper by Hecht on the *Energy Relations in Vision* in which he discusses his experiments determining the minimum energy requirements for vision. Of still more general interest is his demonstration that at threshold values, the variation in the response observed may not be due to the organism concerned, but rather to fluctuations in the stimulus.

This book provides a broad survey of the extremely complex field of visual mechanisms and should prove of interest to anyone interested in these problems. Each paper is accompanied by a bibliography, but there is no index.

TEXTBOOK OF ANATOMY AND PHYSIOLOGY. *Eleventh Edition.*

By Diana Clifford Kimber, Carolyn E. Gray, and Caroline E. Stackpole. The Macmillan Company, New York. $3.00. 8½ x 5½; xiii + 769; 1942.

The average and supposedly educated person possesses a far more accurate knowledge of the construction of his automobile than of the normal form and function of his own body. In partial explanation of this deplorable fact we must admit that man is an infinitely more complicated machine than any car and there is no hood on our body that can easily be lifted so everybody can see our engines running. The latter are ably described in this text-book of human anatomy and physiology for the general, educated reader, willing to concentrate on his studies.

The book first appeared in 1894. That it lived to the present, eleventh, edition speaks for the wide-spread demand for and approval of this systematic presentation of the main facts and reasons underlying the design and specifications for that part of our personalities that can be embalmed at death. It seems a pity that the authors of such a popular book missed the opportunity to spread the gospel of the fascinating history and persisting mutability of our bodies, which is the butter on the bread of plain anatomy.

In its latest issue the present work has been considerably revised, new material has been added, particularly regarding physiology, and many topics have been rearranged for more effective presentation. The number of illustrations has been increased to 352 and these are well reproduced, suitable, and not overburdened by unnecessary detail. A list of reference books, a rather

brief glossary and an adequate subject index are welcome additions.

NEUROANATOMY.

By Fred A. Mettler. C. V. Mosby Company, St. Louis. $7.50. 10 x 6¾; 476; 1942.

The recent years have witnessed the appearance of a considerable number of new English-language textbooks of neuroanatomy. The present volume is distinguished by the generally high quality of its illustrations and by its thorough treatment of the gross anatomy of the central nervous system.

The presentation of microscopic neuroanatomy, however, is less satisfactory. A number of the figures are taken from sections that have been cut at orientations different from those that will be encountered by beginning students, and hence must be confusing. The functional presentation of the subject leaves much to be desired. This seems most unfortunate, for neuroanatomy cannot be successfully taught as a purely morphological discipline, and can have but little meaning unless it is closely and skillfully correlated with neural functions.

MORRIS' HUMAN ANATOMY. *A Complete Systematic Treatise. Tenth Edition.*

Edited by J. Parsons Schaeffer. Contributors: Leslie B. Arey, Raymond F. Blount, Eliot R. Clark, Harold Cummins, J. C. B. Grant, J. F. Gudernatsch, C. M. Jackson, Franklin P. Johnson, Olof Larsell, Bradley M. Patten, Richard E. Scammon, J. Parsons Schaeffer and Robert J. Terry. The Blakiston Company, Philadelphia. $12.00. 10½ x 7; xi + 1635; 1942.

This is the tenth edition, and the first in nine years, of one of the more widely used text-books of human anatomy. Not only is there a new editor-in-chief, but also new editors of five of the sections. Numerous figures have been added and some of the old ones omitted.

Some of the changes distinctly are for the better, notably those relating to the nervous system. The reviewer is pleased to note that the new editor of the muscular system has not radically altered the presentation of this section, which in most respects is the best that has yet been written.

PHYSIOLOGY AND PATHOLOGY

DOCTOR BARD OF HYDE PARK. *The Famous Physician of Revolutionary Times; the Man Who Saved Washington's Life.*

By John Brett Langstaff. Introduction by Nicholas Murray Butler. E. P. Dutton and Company, New York. $3.75. 8½ x 5¾; 365; 1942.

It is a good thing now and then to have put before us material such as Langstaff has so painstakingly gathered together in this volume, to make us more conscious of the difficult beginnings of much that is now almost taken for granted.

Dr. Samuel Bard (1742–1821) was one of the pioneers of American medicine. His father John Bard was a well-known physician who had received his training in Philadelphia in the then usual way of serving an apprenticeship in the office of a practicing physician. At the age of 30 he left Philadelphia for New York on the advice of his close friend Benjamin Franklin who praised him as "an ingenious physician and surgeon and a discreet, worthy and honest man". In New York he enjoyed a prosperous practice and was instrumental in establishing an infirmary which has expanded into the present Bellevue Hospital. When his son Samuel decided to follow his father's profession, John Bard decided to give him a better medical education than he himself had been able to get. Arrangements were made to have him study in Edinburgh. This Scottish university was at that time one of the leading medical schools of the world, with a faculty of eminent scientists attracting students from far and wide. While a student at Edinburgh young Samuel began to realize the great need for higher standards in American medicine and resolved to do something about raising them. A year after his return from abroad he and five other physicians succeeded in persuading the governors of King's College (now Columbia University) to "institute a medical school within this college for instructing pupils in the most useful and necessary branches of medicine." He himself held various professorships and in time became dean of the faculty of medicine, and finally president of the reorganized College of Physicians and Surgeons.

At a commencement address at King's College soon after he had become a professor he spoke of the "duties of a physician with some sentiment upon the usefulness and necessity of a public hospital". This was the beginning of a movement which ended in the erection of New York Hospital. Aside from his scientific and civic interests he was an important practitioner of medicine. "Perhaps", wrote one of his colleagues, "there never was a medical man in the city of New York so universally known, so much beloved and esteemed as a practitioner. Indeed, so astonishingly popular was he at one time that, notwithstanding the number of worthies who flourished contemporaneously in the same city, he was called to almost every person who was taken sick." George Washington was probably his most famous patient. Even after his retirement, at the age of 56, to his Hyde Park estate, he continued his activity in the organization of medical and agricultural societies throughout the state.

Langstaff has succeeded very nicely in giving us a well-written, scholarly account of this notable example of the public-spirited American physician of the late 18th and early 19th centuries whose influence did so much towards shaping the practical course of later American medicine. The book is definitely superior to many of the "doctor books" which have appeared so frequently in the past several years.

SPONTANEOUS AND EXPERIMENTAL LEUKAEMIA IN ANIMALS.

By Julius Engelbreth-Holm. Translated from Danish by C. L. Heel. Oliver and Boyd, Edinburgh and London. 15s. 8¾ x 5½; xxiii + 245; 1942.

Leukemia, a disease of the blood cell-forming organs similar in many respects to cancer, first became known in the human organism about 100 years ago. Later, its presence was discovered in the horse, pig, dog, and cat. In 1868 it was observed in birds. Many attempts were made to transmit the disease from one animal to another but it was not until 1908 that Ellermann and Bang, Danish workers, were successful in transmitting leukemia from diseased to healthy fowl. Since that time and particularly within the last decade, a great deal of work has been done in the laboratory with animals, especially with mice, in the hope of throwing light on the occurrence of human leukemia and its near ally, cancer. The approach to the problem has been along widely different lines—physiology, biochemistry, genetics, radiology, pathology, etc.—with the result that a great mass of observations has accumulated.

The present book was written at the invitation of the Scientific Advisory Committee of the Lady Tata Memorial Trust, a Trust founded in 1932 by the late Sir Dorabji Jamsetji Tata, of Bombay, in memory of his wife. The Danish manuscript was completed early in 1940. To the English version certain further references to important publications have been added by the Committee. The pioneer work of Engelbreth-Holm on avian leukosis, as well as his later contributions in the field of mammalian leukemia and his wide knowledge of the literature on the subject, have enabled him to write an authoritative treatise. His aim has been "to review the collective knowledge of spontaneous and experimental leukaemias in animals and to discuss the relationship which these conditions bear to the problem of leukaemia in man."

Part I of the book is devoted to spontaneous leukemia in birds and mammals; Part II, to transmission experiments in fowl leukemia, virus of fowl leukemia, and transmission of mammalian leukemia; Part III, to heredity in the spontaneous development of leukemia and the significance of heredity in transmitted mouse leukemia; Part IV, to experimental production of leukemia in fowls and in mammals; and Part V, to the nature of the animal leukemias, and the relation between human and animal leukemias. The author believes that "there can be no legitimate grounds for doubt that leukaemia in animals, especially in mice, is the same as leukaemia in man."

The volume is completely documented and indexed. It will be of great value to research workers in this field.

BLOOD GROUPING TECHNIC. *A Manual for Clinicians, Serologists, Anthropologists and Students of Legal and Military Medicine.*

By Fritz Schiff and William C. Boyd. Foreword by Karl Landsteiner. Interscience Publishers, New York. $5.00. 9 x 6; xiv + 248; 1942.

This volume is based largely upon Schiff's German book on the same subject. It is, however, by no means a mere translation, but has been greatly revised and brought up to date and this, after Schiff's untimely death, by the American author. The main purpose of this useful volume is to present concise directions for undertaking blood grouping tests in connection with transfusions as well as for cases of disputed parentage and various medicolegal purposes. Special attention has also been given to the important contributions of blood grouping studies to anthropological problems, including that of man's place among primates. Both the theoretical and the practical phases of the young and flourishing science and technique of blood grouping are clearly and comprehensively discussed. To each section is added a selected list of references which will readily lead the student to further information.

The large and practical section on the many technical aspects of blood grouping preliminary to blood transfusion is especially welcome at present in connection with military medical requirements, though certain phases may now become rapidly replaced by technical innovations resulting from the intensive new research in this field. The section devoted to blood group investigations in anthropology is of particular interest to biologists. This section is at times rather speculative and perhaps too enthusiastic in some of its far-reaching, hypothetical conclusions.

The book is intended primarily for scientists, but is of interest also to the legal profession. To the former some discussions (e.g., the lengthy remarks on who is and who is not a blood grouping expert) and illustrations (e.g., the full-page diagram of figure 28, showing "possible" and "impossible" fathers of a cute illigitimate baby) may appear as quite unnecessary or unduly popularized.

There is a serviceable subject index.

HOW TO LIVE IN THE TROPICS.

By Virginia Lloyd Hunt. Harcourt, Brace and Company, New York. $2.00. 8½ x 5⅝; ix + 178; 1942.

When one is confronted by the possibility of living in the tropics, he is likely to anticipate it with blind enthusiasm or with fatalistic despair. Miss Hunt attempts to dispell false hopes and fears by stressing a realistic approach fortified by a knowledge of existing conditions. She relates with equal emphasis both the pleasures and hardships associated with living in the tropics. The book is written in a friendly, conversational style which convinces the reader that the author is attempting to help. The reading of the book encourages a person to make the best of the hardships while enjoying the unique pleasures and opportunities which the tropics afford.

The book contains a wealth of information on a variety of subjects dealing with tropical life. A chapter on "preparations" offers many practical suggestions to the inexperienced traveller who is preparing for his first sojourn in these regions. Other chapters, such as "insect enemies" and "victuals and drink" record many specific facts that should prove helpful after one arrives in the new environment. Inasmuch as medical advice and assistance might be difficult to obtain in certain regions, there are three worthwhile chapters on "communicable diseases", "home nursing", and "emergency first aid". Questions of child care and feminine hygiene are discussed as well as the servant problem. Four other chapters treat in more general terms the importance of "climate", "environment", "hobbies", and the "daily routine of keeping fit". The several pages preceding the index are devoted to a list of books that contain additional information on tropical conditions.

SIXTY-FIRST ANNUAL REPORT OF THE DEPARTMENT OF HEALTH *for the Year Ending December 31, 1940. Volume 2. State of New York. Legislative Document (1941), No. 28.*

By Joseph V. DePorte. Albany, New York. 9 x 5⅝; cxxxiv + 253; 1942.

DePorte's review reveals many interesting facts concerning the population of New York State for the year 1940, particularly when these statistics are compared with earlier statistics for the same categories. Statistics are given for death rates for various diseases, marriages, population growth, immigration, change in sex composition, as well as many other phases of population growth. Numerous tables exhibit and analyze the data.

It is only possible, within a limited space, to call attention to two of DePorte's findings:

(a) "Maternal mortality has declined in astonishing degree. . . . In the twenty-year period 1913–1932 (excluding the influenza year 1918) the rate fluctuated between 49 and 60 deaths for every 10,000 live and still births. In 1934 the rate began to drop and in the brief span of six years it came down to the present record low figure of 29—less than half of the rate in 1933."

(b) ". . . in the last decade when in the face of an increase of 900,000 in the total population, the number of children under 5 years decreased by 150,000 and children between 5 and 15 by more than 220,000; at the same time the number of persons 65 years of age and over increased by a quarter of a million. Ten years ago 250 out of every 1,000 persons in the State were children under 15 years; the present proportion is but 206, a drop of 18 percent. In the country as a whole the number of children less than 15 years of age decreased from 294 to 251 per 1,000, a reduction of 15 percent. In other words, this State not only has relatively fewer children but their number is decreasing faster than in the rest of the country."

DISEASE AND THE SOCIAL SYSTEM.

By Arthur Guirdham. George Allen and Unwin, London. 10s. 6d. 8½ x 5½; xvi + 239; 1942.

If the average intelligent reader can curb his anger and restrain his inclinition to toss the book aside as the inconsequential ranting of a none too coherent malcontent, he will be rewarded as he progresses through the volume with many provocative suggestions and stimulating speculations. The organization of the book is rather sketchy and the author's style distinctly tiring. Page after page consists of short, staccato sentences each occupying half a line or less. The reader would appreciate having these random jottings properly coordinated and developed for him.

The author argues that the beliefs we inherit are responsible not only for psychological, but for physical disease. He says that man acquires the diseases permitted in his social stratum, and opines that psychological and physical diseases are interchangeable, and that physical diseases are the patient's solution of psychological situations. There is much about "stress and strain" and the dire consequences thereof.

The book is in four sections. The first deals with personality in relation to disease, the second section explains how most chronic disease is neuropathic in nature and attributable to the effect of abnormal emotion on vulnerable personalities, the third section reviews the effect of the social system in providing a background conducive to abnormal emotion, while the last section deals with tendencies in medicine which the author feels prevent our dealing adequately with current problems. The book is non-statistical and undocumented, quite deliberately, the author points out. The inclusion of an index would have increased the value of the book. If your blood pressure can "take it", you will probably react to this book much as you would to a cold shower.

THE MODERN ATTACK ON TUBERCULOSIS.

By Henry D. Chadwick and Alton S. Pope. Commonwealth Fund, New York. $1.00. 8¼ x 5⅜; vii + 95; 1942.

This handbook makes no pretense of adding to the sum of our knowledge of tuberculosis. Sufficient knowledge is already available to make the eradication of tuberculosis a possibility within a few generations if the established techniques are effectively applied. The attempt has here been made to provide a concise digest of the experience of many workers and of present-day practices in a form serviceable to the health officer and administrator. Because the facilities for tuberculosis control and forms of public health organization vary so widely, even in different parts of this country, emphasis has been placed on the principles rather than on the exact methods that have proved productive. Prevention has been a more potent factor than treatment in the reduction of tuberculosis and, at the present level of morbidity, understanding of the epidemiology of the disease is considered by the authors essential to the planning of an effective control program. The authors discuss the current problems in tuberculosis control and the operation of an effective regional control program. Modern procedures are stressed, especially with regard to the discovery and control of the disease by age, sex, occupation, and within the family, and with regard to the function of the tuberculosis sanatorium. The book concludes with a chapter on "A community campaign of eradication." A bibliography and an index have been appended to the volume.

Health officers, public health nurses, physicians, and others concerned with community health will find this book a useful, brief, and authoritative discussion of ways and means to control and eventually to eradicate the disease.

ALCOHOL EXPLORED.

By Howard W. Haggard and E. M. Jellinek. Doubleday, Doran and Company, New York. $2.75. 8⅜ x 5¼; vi + 297; 1942.

Whether teetotaler or consummate imbiber, alcohol assumes an important rôle in the every day life of modern man. The former dwells on its evils and consigns all drinkers to the Devil, while the latter continues to enjoy his beer and is determined to do so, Volstead or no. As a consequence, so many ideas have sprung up around the effects of alcohol, whether from a physiological point of view, or from its deleterious consequences to society, that the real truth has been obfuscated by half-truths, propaganda, and general ignorance. It is therefore most welcome to receive an unbiased and comprehensive review of the situation. This volume, the third in the series of scientific books for popular consumption selected by the American Association for the Advancement of Science, sets forth the facts that have some foundation for their acceptance. Realizing that alcohol is a touchy topic for many, the writers have been most careful to define their terms, to cite any controversial references, and to draw conclusions only when sufficient data are available to warrant a definite statement. We therefore heartily recommend that this volume be read for its wealth of material on a subject that all love to argue about but about which most are so ignorant, and concerning which, as the writers admit, there is still so much to learn.

FATIGUE OF WORKERS: *Its Relation to Industrial Production.*

By the Committee on Work in Industry of the National Research Council. Reinhold Publishing Company, New York. $2.50. 9 x 6; 163; 1941.

In these critical months, when everyone is being urged to work harder and produce more, the results described in this timely book are nothing less than startling. This is particularly true in the case of business executives, engineers, personnel workers and students of industrial relations. The volume should be welcomed also by the general reader who is bewildered by the labor problems arising from the National Defense Program.

The aim of this investigation, carried out by a committee appointed by the National Research Council, was to determine the physical and mental reactions of industrial workers to the conditions to which they are exposed in their daily work. In an unbiased and objective way, it reveals not only the direct causes of fatigue, but the psychological origin of strikes, slowdowns and voluntary limitation of output by workers, which waste so much time every day. In addition to working conditions in factories, several other types are considered. One of the studies described—the effects of working at high altitudes—is of considerable practical significance in the training of airplane pilots; another, dealing with the influence of heat, is important in securing the maximum of both efficiency and comfort in projects involving prolonged effort at high temperatures. There is neither bibliography nor index provided.

It seems quite safe to suggest that a careful study of the principles stated and conclusions reached in this book will well repay every business man, executive, personnel director, and student of industrial relations.

NUTRITION AND VICTORY: *Food Problems in War and Peace.*

By Erwin Pulay. William Heinemann, London. 6s. 8¾ x 5¾; 118; 1941 (paper).

During the first World War, we had to deal with many diseases caused by malnutrition, but at that time there was little knowledge of the part played by vitamins in regard to these diseases. Many people believe that the forces of hunger and malnutrition behind the lines were quite as effective in the achievement of eventual victory as the force of arms on the battlefield. So, in the present conflict, the resistance of our armed forces and of our civilians is directly dependent on correct nutrition. The present book deals with many aspects of the nutrition question, emphasizing the importance of protective foods and the utilization of vitamins. It also explains how far mental states can be influenced by diet, which would seem to be a significant factor in our total war effort. Using the scientific knowledge and resources of today, the author shows how we can now improve the efficiency of workers and soldiers, rendering them less liable to fatigue of mind and body. Some of the more important material presented includes: the experience of the last war, food requirements, protective food, the work of the vitamins, balanced diet, dietetics in modern therapy, epidemics, fatigue and efficiency, food and the mind, and civilization and diet. The author, a clinician, has here attempted to combine a popular review of dietetics for the layman with more recondite information for the expert. There is neither bibliography nor index.

This is a stimulating little book and deserves a wide reading among laymen and scientists alike.

WAR MEDICINE: *A Symposium.*

Edited by Winfield Scott Pugh. Philosophical Library, New York. $7.50. 9 x 6; 565; 1942.

It is believed by most authorities, based on the experience of the past, that the present war will make numerous significant contributions to the advancement of medicine and surgery. This is one of the few salutary gains for which war itself can claim full responsibility. The volume under discussion, a symposium, represents a very successful attempt to record and explain some of the major procedures in medicine and surgery that are expected to be needed in the treatment of current war injuries of all sorts. In addition, this book also gives valuable information concerning improvements, refinements and modifications in technique which have come as a result of our experience so far in the present conflict and which can be utilized to advantage throughout the remainder of the war. The material is presented in three general sections—surgery, aviation and naval medicine, and general medicine. The 65 authors, British and American, speak authoritatively and convincingly, with a readily apparent understanding of their subjects. Most of these articles have previously appeared in various British and American professional journals and bulletins. The excellent illustrations are a distinct feature and add immeasureably to the value of much of the subject matter discussed. The concluding chapter on selective service psychiatry will be of special interest to many. Lists of references are given at the end of many articles. There is no index.

The book should certainly be required reading for those doctors already in service with the armed forces or about to begin such service, and the average practicing physician will find much in it of genuine interest and value.

THE PLEURO-SUBPLEURAL ZONE: *Its Clinical and Experimental Investigation and Its Practical Importance in Chest Pathology.*

By J. Skládal. Cambridge, At the University Press. $2.75. 8½ x 5½; vii + 103; 1942.

Skládal herein presents his method of determining latent phases of chest diseases. He holds the pathology of the pleuro-subpleural zone "to be the key-point of the proper pathology of the lungs, the latter being physically an elastic organ enclosed in the thoracic cage, but in free communication with the outer world." He believes that many lung diseases, in the incipient stage, are localized in the lung border and that the presence of these diseases can be determined with the stethoscope and the method of *sudden expiration.* While in many cases, normal deep breathing, supplemented by the cough is sufficient, there are others where this method is not sufficient. The sudden expiration, he finds, frequently reveals warning sounds that could not otherwise be perceived. During auscultation by means of sudden expiration a double expiratory sound may in some cases be heard, or, less frequently, three auscultatory sounds (the pulmonary gallop rhythm).

The author describes in full his researches, commenced in Prague and continued later in Paris. These include stethacoustic and radioscopic examinations, and the employment of oscillography and aerotachography. Eleven plates and 20 figures are given in the text, an index of definitions is furnished in an appendix and there is a bibliography of 20 references, but no index.

HEREDITY, FOOD, AND ENVIRONMENT IN THE NUTRITION OF INFANTS AND CHILDREN.

By George Dow Scott. Chapman and Grimes, Boston. $5.00. 8½ x 3¾; xvii + 778; 1942.

This extensive study of the nutrition problems of infants and children covers the factors involved in heredity, biology of the cell, disease, resistance to disease and metabolism, including references to the primitive

practices of disease prevention, before discussing the pertinent facts of infant nutrition.

The special sections on foods, including milk and its products, vegetables and fruits present a great amount of excellent material. The food journey through foreign lands with typical recipes is most interesting. The vitamins are discussed individually and in relation to the various foods. However, the author does not include the addition of vitamins to butter substitutes and cereals.

The final chapters correlate the physical and psychic stimuli and physiologic processes in the balancing of metabolism of young children. The bibliography at the conclusion of each chapter together with page references add to the value of the book. A glossary would be advisable if intended to help the average parent. As a reference book, the absence of an index detracts from the usefulness of the volume.

MEMORABLE DAYS IN MEDICINE. *A Calendar of Biology and Medicine.*

By Paul F. Clark and Alice Schiedt Clark. University of Wisconsin Press, Madison. $2.00. 7¼ x 5¼; 305; 1942.

Here is a truly delightful little book and one which should be welcomed heartily by teacher, student, physician and layman alike. The volume is filled with the odds and ends of biography and history—triumph, tragedy, comedy—that help to drive home a lecture point, enliven the lecture hour with an apt anecdote, or call attention to anniversaries of scientists. Major discoveries, lives given for science, and queer whims and fancies and amusing remarks of the great turn up in these pages, garnered from sources well known and little known, ancient and modern. Each citation appears under its own date in the calendar year, and under each day the items are placed in chronological order for quick and easy reference. In most instances, the birth day rather than the death day of those listed has been used for the date of entry. The series of excellent photographs of many of the distinguished men about whom data are given is a significant feature and adds much to the enjoyment of the book. A comprehensive bibliography and a complete index have been included. For a few hours of very interesting and very instructive reading, we heartily recommend *Memorable Days in Medicine.*

PAIN.

By Thomas Lewis. The Macmillan Company, New York. $3.00. 9¼ x 6; xiii + 192; 1942.

Medical men, and other workers in the biological sciences as well, will welcome this brilliantly written monograph on the nature of physical pain. Although in a sense it largely is an exposition of the personal researches and interpretations of the distinguished inventor of the "nocifensor" system of nerves, it also includes a well-considered and critical review of the pertinent literature relating to this complex and important subject. Even where the reader is inclined to differ with the author's interpretations, he feels that there is no possibility of their light dismissal.

It is unfortunate, however, that the manuscript was completed just prior to the publication of the significant work of Weddell, which explains for the first time the phenomenon of "protopathic sensibility" and contributes so greatly to our understanding of the pattern of cutaneous innervation.

TÉORIA Y PRÁCTICA DE SANIDAD PÚBLICA PARA MEDICOS Y SANITARIOS.

By Juan Moroder. Salvat Editores, Barcelona and Buenos Aires. 9 x 5¾; xvi + 728; 1941.

The organization, administration and work of the various departments—epidemiology, maternal and infant health, nutrition, mental hygiene, sanitary engineering, vital statistics, etc.—are described in this textbook. Numerous laboratory and clinical procedures are included. Although written primarily for the use of public health workers and physicians in Spain and South America, this book should be of value also as orientation reading for Spanish-speaking students, not yet familiar with the English language, taking courses in the schools of public health in this country.

BIOCHEMISTRY

THE BIOLOGICAL ACTION OF THE VITAMINS: *A Symposium.*

Edited by E. A. Evans, Jr. University of Chicago Press, Chicago. $3.00. 9¼ x 6; ix + 227; 1942.

This volume is a record of part of the *Symposium on Respiratory Enzymes* and the *Biological Action of Vitamins* which was held in connection with the 50th anniversary celebration of the University of Chicago. The section on *Respiratory Enzymes* has been published separately (reviewed in Q.R.B. v 17, n. 4).

The great volume of literature on the vitamins which has accumulated during the past few years has made it essential for most biologists to depend upon reviews of one kind or another in their efforts to keep up with the progress being made in this field. Books such as this volume aim to meet this need, and although the various accounts are necessarily short and incomplete, they do bring together a great mass of knowledge about the vitamins and offer a starting point from which

various specific subjects may be more thoroughly investigated.

Although the title would seem to indicate a discussion of the fundamental mode of action of the vitamins, there is an adequate discussion of this point only in the chapter by Ochoa on cocarboxylase. In many cases the discussion of specific function must be omitted because of lack of knowledge, but a great deal is known about such things as the function of riboflavin and particularly the relation of nicotinic acid to the coenzymes which are not discussed in the present volume. The material, however, has been covered in the volume dealing with the other section of the symposium.

The shortage of biochemical information is compensated for by a considerable discussion of the clinical aspects of vitamin action. A number of chapters on the commoner vitamins are written from a strictly clinical viewpoint and clinical results are considered in other chapters where they are applicable.

A chapter on the Economy of phosphorus in the animal organism, by McLean, is included although a very limited mention of vitamin D is the only effort to correlate this with vitamin action. The chapter discusses the general aspects of phosphorus metabolism in the body, but particular emphasis is laid upon bone formation and the place of phosphorus in energy transfer is only mentioned.

Each chapter is accompanied by a bibliography, but there is no index. On the whole, this book should be of value to most biologists as a short summary of our present-day knowledge of the vitamins. The emphasis placed upon the clinical aspects of vitamin problems adds to its value for the physician and interested layman.

FORENSIC CHEMISTRY.

By Henry T. F. Rhodes. Chemical Publishing Company, Brooklyn. $5.00. 8¾ x 5½; viii + 214; 1940.

The fact that forensic chemistry has rarely found its way into general chemistry textbooks is ample reason for the appearance of this fascinating yet scientifically sound volume. Although some of the materials discussed herein represent the published or unpublished contributions of other investigators, it is clear that the author has had first hand experience with most of the techniques and procedures outlined.

Part I of the text carries a detailed discussion of the use of chemistry in identifying the individual. This discussion deals with the application of chemistry to the development of finger prints on a large variety of substances, the classification of a multitude of metallic, organic, and occupational dusts, and the identification of ashes. Full cognizance is taken of the hazards as well as the merits of the accepted techniques.

Part II centers around the application of chemical methods to the proof of "corpus delecti." The materials of this section occupy the greater part of the text, and are concerned with the chemical examination and identification of inks, paper, counterfeit money, firearms, explosives, stains and toxic agents.

It is felt that the author has fulfilled his object in preparing this text: namely, he has synthesized the pertinent facts of chemistry as applied to criminology, and has correlated these facts with the increased use of the microscope, the X-ray, and the deductive method of science in dealing with the identification and the conviction of the criminal.

The text is documented with a list of some 150 references, and is indexed by names and by subjects.

ANNUAL REVIEW OF BIOCHEMISTRY. *Volume XI. Edited by James Murray Luck and James H. C. Smith. Annual Reviews, Inc., Stanford University P.O., Cal.* $5.00. 8¾ x 6; ix + 736; 1942.

The *Annual Review of Biochemistry* has come to be an indispensable reference for many biologists and chemists and this volume should prove no exception. It provides a concise and authoritative summary of current work in the field and a point of orientation for those desiring to do further reading on a particular subject. This latter function is becoming increasingly important as biochemical methods are extended to an even increasing number of biological fields. In spite of the war, the number of papers reviewed in this edition is not significantly less than in previous years, although American and British papers necessarily make up a larger percentage of the total.

In addition to the large number of well-chosen topics which are covered regularly by the *Annual Review*, three new topics appear: Avian biochemistry, Plant tissue cultures, and The chemistry of visual substances. These have been added in response to the increased activity in these fields, particularly the first two mentioned, which have only recently come into prominence. There is also a chapter on Biochemical and nutritional studies in relation to the teeth, a subject which has not been reviewed here since 1934.

As usual each article attempts to provide a complete bibliography of the pertinent literature, and there are excellent author and subject indexes.

THE DYNAMIC STATE OF BODY CONSTITUENTS.

By Rudolf Schoenheimer. Harvard University Press, Cambridge. $1.75. 9 x 6; x + 78; 1942.

This short volume consists of three lectures drafted by the author before his death. They were revised by his colleagues and delivered by Dr. Hans T. Clarke at the Harvard Medical School. In an introduction

Clarke gives some biographical details of Schoenheimer. He was a pioneer in the use of isotopes of hydrogen, nitrogen and carbon as tracers in order to follow the rapid interchanges which take place in normal metabolism. In these lectures, he presents very simply an exciting summary chiefly of his own work, confining the discussion largely to the physiological results and interpolations, and omitting any detailed discussion of the methods employed. In the first lecture, he shows how in the normal animal, the relative constancy of the body fats is maintained by a multiplicity of chemical changes in a rapid and constant state of flux, including direct replacement of chemically identical fatty acids, and their desaturation, degradation, elongation, and reduction to alcohols. In the second lecture, he shows that the relatively constant protein composition of normal animals similarly masks a very active series of chemical transformations and interchanges in the amino acids. In the third lecture, he traces the internal mechanisms that lie behind the formation in the body of certain excretory substances such as urea, creatines, and uric acid. The book is very readable and the format is excellent.

ORGANIC REAGENTS IN INORGANIC ANALYSIS.

By Paul von Stein. Chemical Publishing Company, Brooklyn. $4.50. 8½ x 5½; v + 242; 1942.

In this compendium of metallo-organic reagents, the author has brought together a wealth of pertinent data concerning organic compounds which yield specific reactions with inorganic materials. The work has been organized and prepared from the standpoint of clarity and brevity and is not intended so much for use as a textbook, or even a laboratory handbook, as that of a complete reference for the chemical analyst whose work requires the most accurate as well as the simplest and most rapid techniques available.

Some 45 elements are listed alphabetically, together with the methods of preparing numerous organic compounds from each. Great care has been exercised in indicating the regard for detail which is essential to successful analysis. Wherever possible, the margin of sensitivity of the reaction is indicated, and the most suitable substitute reagents are listed. The paragraph on each compound is concluded with a list of references of the original investigations from which the materials have been assembled.

Appendices on the preparation of reagent solutions, and a partial summary of reagents and interferences in detecting metals are included. A complete index is appended.

PHYSICAL CHEMISTRY FOR STUDENTS OF BIOCHEMISTRY AND MEDICINE.

By Edward Staunton West. The Macmillan Company, New York. $5.75. 9¼ x 6½; xiv + 368; 1942.

This book is a presentation for college and medical students of those aspects which seem to the author to be particularly applicable to biochemistry and medicine. Behind the brief introduction lie nine chapters: structure of matter; gases and solutions; osmotic pressure; electrolytic dissociation and the mass law; acids, bases and buffers; the determination of pH; the colloidal state and membrane phenomena; oxidation and reduction; velocity of reactions. Following each chapter is a list of exercises, and a very brief list of general references. It is a debatable question whether a partial presentation of selected aspects of physical chemistry with a bias toward biochemistry is more of an aid to biological students than a more general attack on the subject. However, granted the premise of the author, the book is quite up-to-date and achieves its end. The previous background of the student is reviewed wherever necessary, so that the student may follow the presentation as the subjects unfold.

SEX

SEX FULFILLMENT IN MARRIAGE.

By Ernest R. Groves, Gladys Hoagland Groves, and Catherine Groves. Introduction by Robert A. Ross. Illustrations by Robert L. Dickinson. Emerson Books, New York. $3.00. 8⅜ x 5½; 319; 1942.

"Here, the goal is to give, first, information that the newly married will want that they may be able to cope better with their new sex experience, and, second, facts that all married persons need to know if they are to get from their sex life together all that it has to give. To discuss mental abnormality, disease, malformation, and other problems outside the usual personal experience of the average man and woman, would be likely to cause a misunderstanding of the importance of these things as they affect the normal person and might easily lead to exaggerated and groundless fears."

This goal has been nicely achieved by the authors who reveal a complete and intelligent understanding of the problem of sex relationships. The majority of books on the market fail in their mission by not making sex and its related phenomena appear as a normal and natural part of man's behavior. The latest trend has been to so-called frankness of discussion, a truism used to allow emphasis on techniques, abnormalities, frustrations, libidos, and on other phases that are of no concern to the normal average person. By avoiding this pitfall, and by ably presenting the facts in a sympathetic manner, the authors have written a commendable and helpful book for those not only already married but also for those contemplating marriage.

SEX EDUCATION IN HIGH SCHOOLS.

By John Newton Baker. Introduction by William E. Cole. Emerson Books, New York. $2.00. 7⅜ x 5; xiii + 155; 1942.

Because of the high incidence of illegitimacy and rape, and because of the general ignorance concerning sex, as well as an appalling amount of incorrect information about it among high school children, the author maintains that sex education should begin in the high school. The objectives of such an education, the opposition to be met, the type of instruction to give, as well as other problems and prospects are discussed.

BIOMETRY

BARLOW'S TABLES *of Squares, Cubes, Square Roots, Cube Roots and Reciprocals of All Interger Numbers up to 12,500. Fourth Edition.*

Edited by L. J. Comrie. E. and F. N. Spon, London; Chemical Publishing Company, Brooklyn. $3.00. 8½ x 5½; xii + 257; 1941.

The usefulness of *Barlow's Tables* is indicated by the appearance of this fourth edition of the original 1814 publication. The plates of the second edition of 1840, edited by Augustus DeMorgan, were used until 1931 when the tables were reset and various improvements were made. The present edition follows the 1931 pattern with an extension of the table to include numbers from 10,000 to 12,500. This increases the book by 50 pages, but the pagination and size of page of the previous edition are maintained.

Barlow's Tables is one of the very convenient tables for the statistical computer, largely because of the limitation of the functions included. This allows all the functions for a given argument to be on the same line, and the required amount of thumbing through the table is therefore reduced to a minimum. Of course this economy would be of no consequence if the functions were not selected with care, but particularly the square, square root, and reciprocal of the square root are continual requirements of the statistical technician. For all computations that include a routine demand for these terms, *Barlow's Tables* is a distinct time saver. The extension of this edition still further enhances its value.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 5, Number 1, March, 1943.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: Some theoretical considerations concerning the interchange of metabolites between capillaries and tissue, by Ingram Bloch; Theory of cellular pulsations, by Henry E. Stanton; The linear theory of neuron networks: The dynamic problem, by Walter Pitts; Outline of a new mathematical approach to general biology: I, by N. Rashevsky.

PSYCHOLOGY AND BEHAVIOR

CHILDREN'S BEHAVIOR PROBLEMS. *A Statistical Study Based upon 2,113 Boys and 1,181 Girls Examined Consecutively at the Illinois Institute for Juvenile Research. II. Relative Importance and Interrelations Among Traits. By Luton Ackerson. University of Chicago Press, Chicago.* $5.00. 9 x 6; xix + 570; 1942.

Volume I of this study on *Children's Behavior Problems* was issued in 1931 under the sub-title *Incidence, Genetic and Intellectual Factors.* The study has had for its aim a quantitative investigation into the many causal factors underlying undesirable behavior manifestations in children. It is based on the assumption that "behavior traits are correlated with a large number of factors either inherent in the child himself or arising in his environment, and that these correlations may vary in magnitude from zero to significantly high values either in a positive or in a negative direction. Thus the individual's behavior pattern is conceived as the resultant of many contributing factors of differing degrees of potency."

The present volume deals with the correlations of 161 frequently noted behavior traits and other case-record notations. Three criteria were designed to indicate the degree of the child's deviation from the conventional norm of acceptable behavior: "(1) *personality-total*, i.e., the unweighted summation of all the personality problems reported for a given child, (2) *conduct-total*, similarly the unweighted summation of all the conduct problems reported for each child, and (3) arrest by police or appearance in juvenile court for reason of misconduct."

Data on each child (all white children between the ages 6–17 inclusive, and with intelligence quotients ranging from 50 to over 150) were obtained from the parents, social workers, teachers, etc., and by clinical examinations in the Illinois Institute for Juvenile Research. Part I (7 chapters) of the volume is introductory. Part II (5 chapters) is concerned with the relative importance among traits. Over eight hundred correlation coefficients were computed for the three criteria—personality-total, conduct-total, and police-arrest. It is only possible in a brief space to note a few of the interesting results. These will give the reader, however, an idea of the manner in which the study was developed.

8. The notations *queer behavior, depressed mood or spells, unhappy appearance or manner, question of change of personality, changeable moods,* and *mental conflict* yielded high correlations with *personality-total* among

both sexes and with *conduct-total* among girls. With *police arrest* their correlations were negligible or zero.

9. *Hatred or jealousy of sibling, inferiority feelings,* and *daydreaming* showed substantial correlations with *personality-total,* low correlations with *conduct-total,* and almost no correlation with *police-arrest.*

11. *Boastfulness or "show-off" manner* and *disturbing influence in the home* showed substantial correlations with both *personality-total* and *conduct-total,* but low or zero correlations with the *police-arrest* criterion.

15. The following showed high correlations for both *conduct-total* and *police arrest,* but moderate or low correlations with *personality-total; truancy from home, truancy from school, staying out late at night,* and (calculated for boys only) *stealing an automobile.*

16. The following showed high correlations with *conduct-total* and moderate correlations with *personality-total* and *police arrest* among both boys and girls: *disobedience, incorrigibility, lying, leading others into bad conduct, diagnosis or question of psychopathic personality,* and *bad language.* Similar correlations were shown by the following four notations, which were calculated only for boys: *threatening violence, begging* (on the street), *"annoying" girls,* and *obscene language.*

20. With the *police-arrest* criterion of seriousness, among both boys and girls, the conspicuous correlations were for such conduct difficulties as stealing, robbery, burglary, truancy from home or from school, associating with bad companions or running with a gang, and staying out late at night. Among girls, the outstanding correlations were for *sex delinquency* (*coitus*) and *over-suggestibility,* both of which showed only low or moderate correlations among the boys.

In Part III (48 chapters) are given the data, arranged in 125 tables of correlation coefficients, on the interrelations of 111 behavior traits. Altogether there is a total of correlation coefficients of about 14,000. However, this part is much more than a collection of statistical tables. In each chapter there is a detailed discussion of the findings.

A book of great usefulness as a source book to those working with children. The arrangement of the material is excellent and it is presented in clear, concise language. A detailed index is provided.

PSYCHIATRIC ASPECTS OF CIVILIAN MORALE.

Prepared by the Military Mobilization Committee of the American Psychiatric Association. Family Welfare Association of America, New York. 50 cents. 9 x 6; 62; 1942.

This is a collection of five unrelated essays differing widely in value. The first two constitute a serious and scholarly attempt to find out just what it is that happens to the minds of people who are coerced into participation in war.

Warfare has been studied in its political, economic, and military aspects, we are told in the opening essay. But its social aspects have until quite recently been neglected by scholars. The present work is an attempt to supply the lack of literature dealing with this phase of modern warfare. It is a thoroughly unprejudiced and sincere effort to get at the facts.

It is significant that such an investigation should be taken up by an association interested in psychiatry. This science was originally a branch of psychology devoted to the study of abnormal mental states—at least, that is the way William James used the term half a century ago. Today it has become a branch of medicine, dealing with methods of treatment of mental diseases. It has transcended the boundary (which, like so many geographic boundaries, may be an imaginary line) between the descriptive and normative sciences.

The most striking result of the investigations summarized in these first two essays is that the chief effect of warfare on the psychiatry of a population is a great increase in the number of psychoneuroses, with no increase in the number of psychoses. Now the increase in psychoneuroses will surprise no one, but there is a wide spread idea that the psychoses of a nation are more numerous in war time. Consequently the thoughtful reader of this pamphlet is likely to speculate as to the possibility of an inverse causal relationship between the psychoses of a population and its bellicosity—that nations go to war because their foreign policies are dictated largely by psychotic personalities.

Of course, no nation would consent to a psychiatric examination of its executive officials, especially when a war is going on, much less to the publication of its result. About all that can be done is to draw inferences from representative samples of the population. This is what the compilers of these essays have tried to do, but in such a brief pamphlet the result can hardly be satisfactory. The work is highly documented with several footnotes to each paragraph, but these merely refer to the painfully meager bibliographies. If the references had been inserted in the text instead, and there given the discussion which they merit, the statements which they support would not appear so dogmatic.

What is really needed is a much more detailed and penetrating treatise, in which warfare shall be analyzed as a cause, as a symptom, and as an effect, and in which all its aspects, even its moral aspect, shall be considered. Its bibliography should cover the literature of the entire field, from the classic essay of Jonathan Dymond and the later works of Frederick C. Howe and Bertrand Russell down to the latest medical and psychiatric reports. Now that the custom of celebrating every quarter century with another world war has apparently met with universal acceptance it behooves the civilized world to seek a better understanding of its new plaything.

The final three essays were not intended for publication with the first two, to which they are perceptibly inferior.

HANDWRITING ANALYSIS: *A Series of Scales for Evaluating the Dynamic Aspects of Handwriting.*

By Thea Stein Lewinson and Joseph Zubin. Foreword by Noland D. C. Lewis. King's Crown Press, New York. $2.00. 8½ x 5½; xiii + 147; 1942 (paper).

The authors of the present book, members of the Psychological Department of the New York State Psychiatric Institute, present a series of scales which they have developed for graphological analysis. They describe graphology as "the art and in some respects the science of interpreting and differentiating individual character and personality on the basis of handwriting." Their method is based on the hypothesis that handwriting "in all its aspects may be regarded as an expressive movement and that this movement may be classified on a contraction-release continuum. By a contracted handwriting is meant a type of writing which is carefully and meticulously executed and which exhibits a high degree of control in the writing movements. By a released handwriting is meant a type of writing which is very loose and which exhibits a low degree of control in the writing movements."

The unit in the analysis is the single letter or a combination of letters. There are twenty-two factors involved, distributed into the following components: (1) the form component (6 factors, characteristics of the form and of the stroke); (2) the vertical component (7 factors, pertaining to height and size-ratios based on the height of the letter forms); (3) the horizontal component (9 factors pertaining to width and size-ratios based on the width of the letter forms); (4) the depth component dealing with degree of pressure (on paper), control, and cursiveness of the writing.

Each of these components is discussed in detail—the material is furnished by five normal and 15 abnormal individuals—and numerous drawings and graphs illuminate the various points. In four appendixes are given (a) general directions for measuring and rating factors, (b) distribution of measures by factors on the contraction scale, (c) charts for obtaining contraction values, and (d) instrument for measuring degrees of curvature. A bibliography of 24 titles is included but the work is not indexed.

DRUGS AND MENTAL DISEASE. *A Review of 841 Cases. Confinia Neurologica, Vol. 4, 1941.*

By Merrill Moore, Alice F. Raymond and M. G. Gray. Reprinted in the United States. 9 x 6; 238–271; 1941 (paper).

The relationship between drug addiction and mental disease is far from being a clearcut phenomenon, and the problem is usually further complicated by incomplete or faulty diagnosis and the maintenance of inadequate records in mental hospitals. In the present 40-page report, the authors have done a good job with what materials were available to them but their written report at times lacks clarity. The study covers a 20-year period (1917–1938) and treats the 841 cases of mental illness due to drug addiction or other exogenous toxins confined to the Massachusetts mental hospitals for that period. The data are tabulated for sex, age, race, economic status, education and nativity.

Several interesting facts are pointed out by the investigation: (1) the recovery rate is high and the death rate is low among cases of mental disease due to drug addiction; (2) the incidence of persons with college education, and persons from marginal (hand-to-mouth) economic status is higher among cases of mental illness from drug addiction than among all admissions for the period studied; and (3) there is a higher percentage of unmarried persons in the group studied than among all admissions to the Massachusetts mental hospitals. Whether these differences are real, or whether they represent the normal variation common to the phenomenon is not determined. The value of the study for either the prediction of trends or for the prevention of mental disorder is questionable, in view of the fact that only 0.7 of 1.0 per cent of all hospitalized cases in Massachusetts for the period 1917 to 1938 were due to drug addiction or other exogenous toxins.

A short list of references is appended.

MENTAL HYGIENE *for Community Nursing.*

By Eric Kent Clarke. The University of Minnesota Press, Minneapolis. $3.50. 9¼ x 6; iii + 262; 1942.

The community nurse may be the first person to detect evidence of mental illness or of conditions that may precipitate mental hygiene problems. She has often the first opportunity to notice abnormality in preschool children, overanxiety in adults, borderline cases in need of observation and guidance, and countless signs and situations that require attention. In an inclusive group of personal histories of children of all ages and of adults, Clarke has given a cross section of the problems that the community nurse may encounter. Authoritative interpretations of what lies behind the maladjustments are described and it is shown how the nurse may help to coordinate the work of every available agency in the task of guidance, treatment, and education in mental hygiene. The material presented is in large part that which forms the basis for discussion periods with the students in public health nursing at the University of Minnesota. There is discussed in order: mental hygiene as a community responsibility, the preschool child, the child at home, the handicapped child, the adolescent, the family, the convalescent and the chronic invalid, the psychoneurotic, the psychotic, community care of the feebleminded, and the mental hygiene of the community nurse. A list of suggested reading material

and an index conclude this timely, well-written and very worthwhile volume. It deserves a wide reading among all those interested in the public health aspects of mental hygiene.

PSYCHOLOGY OF THE CHILD. *Mental and Physical Growth.*

By Joseph William Nagge. The Roland Press Company, New York. $3.25. 8 x 5⅜; xvi + 530; 1942.

Nagge, in this excellent textbook, gives a well-rounded survey of the present status of child study. Throughout the book he reviews the important work of earlier investigators and brings into clear perspective the important steps forward in the development of the subject. While the greatest advances in the study of child psychology have been within the last two decades, Nagge stresses the importance of earlier writers, such as Preyer and Rousseau. After an historical introduction the subject is discussed under the following headings: The behavior of the organism before and shortly after birth; Motor development; The development of perception; The growth of intelligence; The physical growth of the child; Learning and forgetting; The origin and development of language: Personality and social development; Motivation and incentive; Play; Types of exceptional children; and The mental and physical hygiene of the child. In an appendix are given weight-height-age tables. Footnotes indicate the sources of the material referred to in the text, each chapter concludes with a well-selected bibliography and author and subject indexes are provided.

An invaluable source book for the shelves of psychological as well as general libraries.

EDUCATIONAL PSYCHOLOGY.

By Wendell W. Cruze. The Roland Press Company, New York. $3.25. 8 x 5⅜; xvi + 572; 1942.

The author sees psychology contributing to education in two ways: (1) by telling the educator "something about the nature of the individual", the raw material in his hands, and (2) by determining "the most economical methods for producing the results demanded by social philosophy and economic pressure".

This book essays these tasks with parts devoted to the development of the individual toward maturity, the learning process, personality growth and development, and a final part on psychological perspective and prospective.

Considering the fact that any one of these parts could easily be expanded into a text book of comparable size, the author has succeeded in presenting an agreeable bird's eye view suitable for beginning classes in educational psychology.

Each of the eighteen chapters has a summary and a series of questions to be answered by reference to the material of the chapter. There are considerable author and subject indices and extensive footnotes for the use of those wishing to pursue special topics mentioned in the body of the text.

SELF ANALYSIS.

By Karen Horney. W. W. Norton and Company, New York. $3.00. 8⅜ x 5½; 309; 1942.

Horney in the process of discovering what psychiatrists have long known—that patients may and do find curative means with only casual or occasional reference to skilled help. Couched in her own special sort of psychoanalytic concepts and terminology, there is given here a rather convincing demonstration of the thesis bolstered with detailed case material. She recognizes that putting insight to work is of equal importance to its discovery. Self-analysis poses new theoretical problems, concerning the character of the patient-physician relationship. Horney is not afraid of old problems in new guises. Quite rightly she recognizes that self-analysis (perhaps better called "self-scrutiny" in a less exclusive spirit) is better adapted to use with mild or relatively trivial personality maladjustments. To what extent it may replace systematic therapy is left open, with hints as to factors to watch out for, but with encouragement to its more extensive use.

MOTIVATION AND VISUAL FACTORS: *Individual Studies of College Students.*

By Irving E. Bender, Henry A. Imus, John W. M. Rothney, Camilla Kemple and Mary R. England. Dartmouth College Publications, Hanover, N. H. $4.00. 9¼ x 6⅛; xix + 369; 1942.

This important study from the Dartmouth Eye Institute on 124 students, attempts a correlation of the visual status and the motivational factors of the personality. Extensive personality investigations in the best manner, with interviews, and numerous special tests give excellent psycho-portraits of twenty representative cases.

The results show that the visual status (always not far from normal), the complaints regarding it, and efforts to correct it play no dominant role in the general adjustment, but are utilized by the personality in that manner determined by the principal drives and motivations. Specifically academic efficiency was unrelated to visual efficiency; further, the subjective complaints bore a closer relation to the psychological structure than to the visual defect.

The study will do much to put the matter of visual defect into proper perspective in the total adjustment,

and put the ophthalmologist on the alert for psychological factors in all his patients. A valuable contribution to the literature of psychosomatic medicine.

PRINCIPLES OF APPLIED PSYCHOLOGY.

By A. T. Poffenberger. D. Appleton-Century Company, New York and London. $4.00. 9¼ x 6; xvi + 655; 1942.

This revised and enlarged version of the author's *Applied Psychology: Its Principles and Practice*, reflects the growth and maturity of applied psychology, with an effort to present general principles. The enlargement has to do mostly with the vocational branches. Throughout the effort is made to stress the satisfaction of the individual as the most urgent problem of the contemporary scene. There is a chapter devoted to the rise of radio advertising.

The material on medical psychology is rather sketchily presented, and seems rather bloodless and remote from the actual clinical material.

It is refreshing to see achievement and satisfaction made the center of interest and a detailed analysis made of the principal external factors and personal factors helping or hindering these items.

The book is heavily documented from original research and from the literature.

THE PSYCHOLOGY OF HUMAN LEARNING: *An Introduction.*

By John H. McGeoch. Longmans, Green and Company, New York. $4.00. 8½ x 5½; xvii + 633; 1942.

An extensive and detailed elaboration of the chapter on the psychology of learning as it appears in skeleton form in standard textbooks of general psychology.

Thoroughly documented, this book, published post mortem, presents a wealth of material on learning: curves, distribution of practice, as function of the material and methods of presentation, of age, sex, intelligence level, of incentive condition. Retention, transfer, forgetting, fixation, and elimination are all thoroughly discussed.

The bibliography is exhaustive. A most important book on this subject.

DE OMNIBUS REBUS

ET QUIBUSDEM ALLIS

KODACHROME AND KODACOLOR FROM ALL ANGLES.

By Fred Bond. Camera Craft Publishing Company, San Francisco. $6.50. 10¾ x 7¾; 232; 1942.

The urge to picture the world about us is not new. From the earliest of times, man has attempted to record his life and the scenes about his small world. From the mediums of the carvings of cave dwellers, the paintings made from vegetable and fruit dyes, and the crudely sculptured images, to the modern precision camera is a long step. We, of the present, often times take too much for granted the ease and ability by which we can record the world around us.

The advent of color to photography is a far greater scientific gift to the world than we appreciate. It is technically scientific in nature and yet it is prepared for simple effortless usage. So, with the addition of color to photography, a new and larger field is open to the amateur and professional for interpretation in unlimited numbers of ways and effects. The main purpose of this book on kodachrome and kodacolor is to aid the serious, capable non-professional in getting maximum results with any interpretation he wishes.

Beginning with a discussion of color and art, the author calls attention to the important change brought about by the addition of color to photography. One must now consider a new medium and its greater variations, as well as lines, shades and forms, usually considered in black and white pictures. It is necessary to develop an eye for color, to be able to distinguish between good and bad color combinations, to see the influence of one color upon another, to recognize reflected color, and to analyze color for its effect on the finished picture.

Further discussion of color leads to sunlight characteristics and an analysis of the color quality of a variety of sunlight conditions. Detailed procedures are given for analyzing every type of out-door color subject in terms of factors that affect exposure calculations and simple suggestions for every day use.

The treatment of Kodachrome by artificial light should encourage the more timid into taking greater advantage of this light source. A higher degree of control can be obtained with artificial light than with sunlight—light quality and volume, light angles and localized effects can all be controlled. Many diagrams illustrate this control. A useful list of various lamp color temperatures is given. Discussions of the use of photoflash, of the methods for balancing lighting through the use of reflectors and diffusers, and exposure tables, for both still and movie work, illustrate the control of factors that influence results.

Getting on to the actual taking of pictures, the following chapters, each with its problems and practical suggestions, should be of great help and interest. Landscape problems in kodachrome; Portrait, costume studies, still life; Photographing flowers and gardens; and Sunsets, special effects, trick shots.

The addition of color to motion pictures brings about a more realistic interpretation of the world around us. The chapter on better movies in kodachrome confines

itself to problems peculiar to movie work although the material in the previous chapters is just as applicable to movie as it is to still work. The author suggests that many helpful hints can be obtained by studying professional color movies.

The new medium of kodacolor will be of interest to the reader with its process and possibilities explained in detail. The fundamental rules of good color photography apply also to this new medium in securing maximum results.

Discussions on Color correction filters, Color meters, Checking lenses and shutters, precedes the final chapter on Making color prints from kodachrome, which is a non-technical presentation of the subject all color workers should understand to help them appreciate the limitations and possibilities of kodachrome film.

Many large and beautiful kodachrome illustrations increase the attractiveness of the book.

MOLECULAR FILMS: *The Cyclotron and the New Biology Essays.*

By Hugh Stott Taylor, Ernest O. Lawrence and Irving Langmuir. Rutgers University Press, New Brunswick. $1.25. 9 x 6; 95 + 24 figures; 1942.

This little book contains three essays which are related only by the fact that they all show the impact of the physical sciences upon biology, and the application of physical methods in solving biological problems.

The first article by Taylor merely summarizes the high points in scientific development from the 18th century to the present time. Throughout his discussion the author stresses the interrelation of the sciences and points out how one science has picked up and used techniques developed by another. This interdependence has greatly accelerated scientific development in the past and will undoubtedly have an even greater effect in the future, but the author closes with a warning that scientists must become increasingly aware of social problems and the changes which must be brought about to assure that the advances of science will not be misused.

The simple, direct discussion of molecular films and surface phenomena by Langmuir is a beautiful example of how a fundamental and complex problem may be presented to a non-specialized audience. Without losing sight of the fundamental significance of his work, Langmuir shows the development of simple, straight-forward techniques for studying the properties of surfaces, and discusses the implications of the results for other fields, particularly biology. When one considers that he is discussing such accomplishments as making a difference in thickness of 1 Ångstrom optically visible, determining whether a monomolecular layer is in a solid or liquid state, and detecting very fine gradations in the denaturation of proteins, the magnitude of his accomplishment in simplifying the discussion becomes apparent.

Of particular interest are the frequent discussions of the reasoning which led to some of his greatest discoveries. He shows how, by taking relatively simple assumptions and carrying them through to their logical conclusions, he has not only reached new conceptions of certain phenomena, but has also arrived at experimental methods for testing his conclusions. This article is, therefore, of interest both as an example of method and as a simple and direct discussion of surface phenomena.

The final paper is by E. O. Lawrence, the inventor of the cyclotron. He deals primarily with the application of this instrument to the solving of biological problems and the treatment of certain pathological conditions. A great deal of promising work has been done in these fields, but the author wisely points out that the work is too new to warrant unlimited optimism, particularly regarding the treatment of malignancies. However, he does show many and varied applications of this new tool to biological research and points out the great possibilities of the method for future work.

FROM COPERNICUS TO EINSTEIN.

By Hans Reichenbach. Translated by Ralph B. Winn. Alliance Book Corporation, New York. $2.00. 9¼ x 6¾; 123; 1942.

In this captivating little book a very able scientist and philosopher gives us a simplified, readable account of the development of the great problems of space, time, and motion, beginning with the discovery of Copernicus that the sun and not the earth was the center of the solar system, and closing with the still less accessible theory of the Copernicus of our own day—Einstein. The author reminds us that the discoveries of modern science have been made possible only by the abundance of new scientific materials.

Einstein's doctrines are by no means an outgrowth of astronomical reflections alone, but are grounded in the facts of the theories of electricity and light. We are able to comprehend them only in so far as we get acquainted with all their sources. This derivation from several sources is characteristic of the theory of relativity. While the modern sources give rise to the special theory of relativity, the older sources provided the material for the construction of the general theory of relativity in which the old and new knowledge became blended into a magnificent unity.

The first chapter of the book deals with the old material—the discoveries of Copernicus, Kepler, Galileo, and Newton. The antagonisms and the formidable difficulties which these great men had to overcome make us realize "How difficult it must have

been to climb the stairs leading to our present-day knowledge!"

The great English physicist, Sir Isaac Newton, is pictured as the "great unifier" who combined the individual discoveries of Copernicus, Kepler, and Galileo into one magnificent system. "His intellectual achievement cannot be estimated too highly." In the chapters which follow, Reichenbach shows how widely and how consciously new physics has carried out the method of inquiry introduced by these great men.

The greater portion of the book is concerned with giving us a beautifully clear and understandable explanation of Einstein's theory of relativity. This, the author does by means of simple hypothetical experiments that can easily be imagined, and then explains their philosophical consequences. Reichenbach says in closing that "just as the Copernican world view became at last generally recognized and a common property of all educated people, so will it be with the theory of relativity. One hundred years from now, the doctrine will be accepted as self evident; and it will be difficult to comprehend why it encountered at first so much opposition."

PHILOSOPHIES OF SCIENCE.

By Albert G. Ramsperger. F. S. Crofts and Company, New York. $2.25. 8 x 5¾; xi + 304; 1942.

"It is fortunate for mankind that it is possible to have knowledge without being clear as to what knowledge is" we read in the preface. Indeed, scientists have created in the last few hundred years the vast edifice of modern knowledge which has changed entirely the life and outlook of mankind when not only the methods of science but even the existence of a world independent of individual experience was in dispute. Yet there is no doubt that the scientist could profit greatly in the formulation of problems, in the methods of approach, in the construction of theories from a scientific theory of knowledge. Such an analysis of science the author believes to be the most urgent task of the modern philosopher.

The dominating problems of philosophies of science have been the existence of a world independent of human experience and the possibilities of obtaining information about it. The many answers philosophers have given are illustrated with the ideas of Democritus, Aristotle, Descartes, Berkeley, Hume, Kant, Meyerson, Compte and modern positivists. In non-technical language the bearing of the theory of relativity and of the quantum theory upon these problems is discussed. Causality and probability are dealt with in an interesting and original fashion. In the chapter on "measurement" the author points out the merit as well as the limitations of mathematical treatment. Measurements can only inform about relations to a chosen standard. "Objects are related in many different ways and mathematical science does not have a monopoly on true knowledge." Less satisfactory is the chapter on Biological science. The modern attempts to a theoretical biology like holism, organicism, etc. are not even mentioned.

The book closes with a discussion of determinism and morals and the relation of science to human values.

Defending a "relativistic theory of knowledge" the author thinks he has overcome the paradoxes of dualism on one side and of extreme realism or idealism on the other side. All objects of experience are relative and every item in experience is a natural event. Thoughts, feelings, volitions are as much a part of nature as any physical event. "The classification of objects into physical and mental has no ontological basis; it is a matter of convenience. An object or character is physical if it is related in certain ways to others in space and time and does not depend upon conditions which are peculiar to an individual organism."

The book is well suited as an introduction into the main problems of a theory of science, not only for students of philosophy or of the sciences, but equally well for the interested layman. It is written clearly with a minimum of technical terms and reads easily throughout, a character not too common among discussions of this kind.

SCIENCE AND EDUCATION.

By S. R. Humby and E. J. F. James. Cambridge, at the University Press. $1.25. 6¾ x 4; viii + 145; 1942.

This is a plea for a more dignified treatment of science teaching in the English preparatory schools. While the schools of the United States are by no means above criticism of the way in which science is taught in them, the situations in the two countries differ so widely that there is very little in this treatise that is applicable to this side of the Atlantic. The chief value of the work to us is the light that it throws on the modern English curriculum which, according to the authors, is not significantly different from what it was in the lifetime of Galileo.

It does not take much imagination to perceive that all is not well with society. Without attempting to prescribe a panacea of universal application, the authors put the blame for the situation in the British Isles on the antiquated methods of the preparatory schools, in which the belief has grown up that science is a technical subject, and the classics alone have cultural value. The authors wish to shift the emphasis from the classics to science, but they do not wish to exalt technology at the expense of culture. Their criticism of modern English society is that it is not sufficiently cultural, and they believe that science, if

properly taught with due consideration given to its historic aspect, may have a cultural value equal, if not actually superior, to that of the classics. (They offer no comment on the further possibility that the cultural value of the classics may be largely destroyed by the way in which they are taught. The reviewer believes this to be the case in this country.)

The opening chapter, which deals with the short comings of English society is strongly reminiscent of the brief essay on education in William Penn's *Some Fruits of Solitude*, and the social principles enunciated suggest Robert Owen's ill-fated experiment in cooperative living at New Harmony. The fact that at this late date Owen still has his defenders seems to indicate a more or less widespread belief that his failure was due not so much to inherent weaknesses in his social philosophy as in the dishonesty of his associates and his prohibition of any sort of religious expression by his colonists. It is encouraging to realize that his ideals are still alive. The world owes a debt of gratitude to its prophets. Without their exploration of new paths society would be in a sorrier state than it now is.

THE NEW PROJECTION CONTROL. *Third Edition, Revised and Enlarged.*

By William Mortensen. Camera Craft Publishing Company, San Francisco. $2.75. 9½ x 6¾; 123; 1942.

While every photographer strives to obtain the best possible print from any negative, this can only be done through the understanding and utilization of the various techniques involved in projection and contact printing.

The present day use of small cameras makes it almost necessary to know something about projection printing and its adaptability. But despite the tremendous possibilities of projection control, it is little practiced and little understood by the average photographer. Many unfortunately have come to regard it as trick photography. As a matter of fact, projection control offers the photographer a solution to many of his difficulties. It is basically a sound method of producing good prints and in addition permits the individual operator to use his imagination and artistry.

The present volume is a third edition and, according to the author, more than a mere revision and expansion of the old material. Special emphasis is here given to the application of projection control to portrait and landscape photography.

The subject matter discussed includes equipment and materials, negative quality, basic projection printing, local printing, distortion, combination printing, and montage. A most important feature of the book is its stress of the practical and useful methods of projection printing with only slight regard to trick work.

Mortensen also stresses the important fact that the photographer must sustain his best workmanship throughout all stages of photography beginning with the taking of the picture, and should not try to use the methods of projection control to cover up the faults of a poor negative. Given a good negative

the three general types of projection control that are herein described and illustrated are capable of wide and diverse application. Through Local Printing, Distortion, and Combination Printing one may gain greatly increased power over pictorial material. These three procedures when mastered give one control over emphatic placement, control over contours, control over local tone and contrast, control over expressive shapes and forms, and control over the dramatic association of ideas. The procedures described are not easy to apply, although they are simple in principle.

While many practical suggestions for improving one's technique are offered and dealt with in detail, we must not forget that "beyond technique lies the field of personal expression through purposeful and selective dealing with materials".

THE PROGRESS OF SCIENCE. *A review of* 1941.

Edited by S. Edgar Farquhar. Advisory Editor, H. Horton Sheldon. The Grolier Society, Inc., Garden City, N. Y. $2.95. 9½ x 6½; xi + 404; 1942.

A year ago the Grolier Society undertook to publish a year book of scientific progress. The second volume has now appeared. In its six pages of finely printed index are listed in one alphabetization the entry articles in capitals, the biographical articles in minuscules, and the cross references in italics.

In view of the present unsettled conditions throughout the world it is perhaps not surprising that in this book the emphasis has been placed on applied, rather than on pure, science; that invention has been stressed rather than discovery. The arts of war certainly receive more attention than those of peace, but the latter are not neglected, and among the articles dealing with ballistics, the manufacture of munitions, the testing of parachutes, the development of new substances in place of those preempted by war industries, are to be found accounts of Diesel locomotives, the Pit River bridge, endocrinology, colchicine, and the highway to Fairbanks, Alaska. (Incidentally though there has been a crying need for this last improvement for over a generation, and though its construction might have gone far toward dissipating the miseries of the depression, it is doubtful whether it ever would have been put through except as a war measure.)

Among the deaths of scientists occurring during 1941 may be noted that of Ernest E. Just, one of the world's leading authorities on fertilization, who was largely without honor in his own country, owing to the color of his skin. While many readers may not agree with the appraisal of his rank as the foremost biologist of his

line, preferring to accord that distinction to George W. Carver (who, like Just, is a Spingarn medallist) it must be admitted that the failure of the large universities to provide opportunity for Just to prosecute biological research indicate only too clearly how far race prejudice has penetrated even among the intellectual classes. Surely it is not the least function of such a publication as this to give us occasion to appraise the state of our society and to see what progress we ourselves have made during the past year.

HANDBOOK OF SCIENTIFIC AND TECHNICAL SOCIETIES AND INSTITUTIONS OF THE UNITED STATES AND CANADA. *Fourth Edition. Bulletin of the National Research Council Number 106.*

United States Section compiled for the National Research Council of the United States by Callie Hull and Mildred Paddock. Canadian Section compiled for the National Research Council of Canada by S. J. Cook and P. A. Howard. National Research Council, Washington, D. C. $4.00. 9¾ x 6½; 389; 1942.

The purpose of this book is to present a directory to those societies, associations, and similar organizations in the natural sciences and related fields that contribute to the advancement of knowledge. In addition to organizations concerned with the natural sciences and technology, a number of more general organizations and special institutions supporting scientific research have been included. The present edition contains data for 1269 organizations for the United States and its dependencies, and 143 organizations for Canada. Agencies of the Federal government, organizations directly controlled by universities, foundations which utilize their resources for research through grants rather than in the direct conduct of research, and industrial research laboratories are, in general, not included. Indexes to both the United States and the Canadian sections provide a subject classification of the activities, purposes, and research funds of the societies and institutions. A personnel index has been added for officers of the organizations included. Only serial publications of the societies are listed.

Although this handbook is a publication of the National Research Council, the constituent or affiliated societies of the three other national research councils of the United States—the American Council of Learned Societies, the American Council on Education, and the Social Science Research Council—have been included. The data contained should be of real value to all those who require information about the extent and organization of the research agencies of the North American continent.

MIDDLESEX IN THE ELEVENTH CENTURY.

By Sir Montagu Sharpe. Brentford Printing and Publishing Company, Middlesex. 1s. 8½ x 5½; 24 + 2 folding maps; 1941 (paper).

At the time of the Norman invasion Middlesex was a large area lying to the west of the City of London on the north bank of the Thames. Now a large section of it is part of greater London.

The author of this little booklet has long been a student of early Middlesex history. Here he gives a picture of the county as it was eight and a half centuries ago. Much of the material he obtained from the returns of the Domesday Book Commissioners. It is remarkable with what accuracy the size of the landholdings were stated. This could not have been possible had it not been for the system of division and co-aration of the soil established by Julius Sextus Frontinus, Procurator of Britain, A. D. 74. Under his direction "the official land surveyors . . . laid out the Middlesex area as a *territorium* in which to produce food for the rising city of Londinium."

In the eleventh century there were about 7304 persons living in the county, the total acreage of the area being about 181,575. Particulars are given concerning the population—priests, knights, tenants, etc.—their holdings, common pasturage, reclaimable land, meadows, plough teams, water-mills, fisheries, and vineyards. In addition to the records of the county as a whole, the author deals with the economy of one of the important villages (vills), namely, Westminster. Two maps, one a general map and the other a detailed map, add to the interest of the work.

THE ELECTRON MICROSCOPE.

By E. F. Burton and W. H. Kohl. Reinhold Publishing Corporation, New York. $3.85. 9 x 6; 233; 1942.

This book fills a gap in the literature on the electron microscope, for it will appeal to the large group of technical and scientific workers who know more than the popular magazines write on the subject and less than those who are now working with the instrument. This in-between group certainly will include those who will profit by the applications of the electron microscope, and wish to understand the how and wherefore, and those who think vaguely they could use the electron microscope in their own work, but do not know how, out of ignorance of the principles of the instrument. In the first twelve chapters, the authors tell simply of some of the properties of light and electrons. In the last five chapters, they utilize these fundamentals to describe the principles of the electron microscope and its applications. The text is rather non-technical and does not take much for granted on the part of the reader.

There are many magnificent photographs of viruses, bacteria, crystals, and other particles of several sorts taken with the electron microscope. The text is richly illustrated with many simple diagrams, many of which are very amusing, drawn by Dorothy Stone.

SCIENCE IN THE DOCK: *Guilty or Not Guilty?* *By F. W. Westaway. Blackie and Son, London and Glasgow.* 7s. 6d. 8½ x 5⅝; x + 133; 1942.

There has been much discussion within recent times of the value of science to the human race. Science which has so much to offer for the betterment of mankind, is in the present world conflict showing much of its more sinister side. Westaway impartially discusses both sides of the question, quoting freely and at length from the writings of many distinguished scientists, but he comes to no finite conclusion, leaving the reader to decide for himself whether science is guilty or not guilty of the charges brought against it.

The individual who is much perplexed by the rôle of present day science—the cruel and inhuman uses to which great discoveries in chemistry, physics, and metallurgy are being applied, and the profound effect of warfare on the minds of the participants—may perhaps obtain a more balanced viewpoint by reading this book.

CONTEMPORARY SPANISH AMERICANS. *Selections from the Works of Seventeen Modern Writers, Edited with Critiques, Notes, and Vocabulary.* *By Henry Alfred Holmes. F. S. Crofts and Company. New York.* $1.75. 8 x 5⅛; xv + 251; 1942.

This is an introductory work to the literature being produced today south of the Rio Grande. It consists of a series of chapters, each devoted to a single author who is still living or only recently dead. It is obviously intended for use in schools, and is not likely to have a wide circulation elsewhere.

Each chapter is divided into two parts—a summary of biographical details in English, and a selection from the subject's works in Spanish. The latter frequently are brief excerpts from more lengthy works. There is no index but there are twenty pages of notes and thirty of vocabulary, and in a work of this sort they are far more helpful than indices in the two languages could possibly be.

PROCEEDINGS OF THE HYDROLOGY CONFERENCE HELD AT STATE COLLEGE, PENNSYLVANIA, JUNE 30–JULY 2, 1941. *School of Engineering Technical Bulletin No. 27. Edited by F. T. Mavis. Pennsylvania State College, State College, Penna.* $2.00. 9 x 6; viii + 270; 1942 (paper).

This Bulletin contains articles on the recent advances in the science of hydrology. For those not familiar with this discipline, "Hydrology is loosely defined as that branch of physical geography which treats of the waters of the earth in all their states. As a science it undertakes to account for that segment of the cycle which begins with water having fallen to the earth as rain or snow and is to be disposed of through the processes of surface run-off, streamflow, infiltration, groundwater movement, evaporation and transpiration." Most of the articles resolve around flood control.

A PRELIMINARY LIST OF FOREIGN PERIODICALS CURRENTLY AVAILABLE ON MICROFILM. *By Eugene B. Power. Microfilms Inc., Ann Arbor, Mich.* Free. 10½ x 7¼; 8; 1942.